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# ELECTRICAL ENGINEERING

NOVEMBER 1949



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# ELECTRICAL ENGINEERING

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**The Cover:** Operator punching the crust off the top of an electrolytic reduction cell in a modern aluminum plant. About ten kilowatt-hours of electric energy are used per pound of aluminum produced (*pp 928–33*).





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# Ever Try to Take a Poll?

JAMES F. FAIRMAN
PRESIDENT AIEE

**At several AIEE Section meetings, various questions on whether AIEE should expand its activities into nontechnological fields have been asked of President Fairman. Here he discusses those questions and criticisms of major interest or importance to AIEE members.**

IT HAS BEEN my privilege to present the problem—"To Be or Not to Be?"—(*EE, Oct '49, p 829*) at Section meetings in Salt Lake City, Portland, Seattle, Spokane, Amarillo, Oklahoma City, Tulsa, and Charleston, W. Va., and to listen to the lively and constructive discussion which followed. I am looking forward with great interest to similar meetings with about twice as many more Sections before the Winter Meeting. I wish it were possible for me to attend all the Section meetings at which this subject is discussed and to have the opportunity to answer as best I can some of the questions which are bound to arise. It has been suggested that it may be of interest to those Sections which have not yet held a meeting on this subject as well as to the members generally, to hear something about the discussions in which I have participated. I shall attempt briefly to cover those questions and criticisms which seemed to be of major interest or importance to our members.

### AN OBSERVATION

First, I submit one common reaction as an important part of the background for the questions and criticism. So far as I can recall, without exception the members present at those eight Section meetings recognized the need for some organized work by the engineering profession in the field of the so-called nontechnical activities. I expected to be asked what all the shooting was about, but I wasn't. Everyone seemed to know. Everyone seemed to want something more done than has been done up to date and, even more significant, everyone seemed to realize there would be some sort of price tag in the form of dues as well as individual expenditure of time and effort. The question wasn't whether or not something more should be done or whether or not engineers could afford it. Rather, it was why haven't engineers as a profession been doing more and when and how shall they begin.

### THE MAIN WORRY

The principal concern arose from and the most criticism was directed at the form and phraseology of the alternative propositions by which the Special Committee is attempting to obtain the opinions of the membership: "I favor adhering to technical field"; or "I favor expanding in nontechnical field with substantially increased dues." (*EE, Oct '49, p 890*). The propositions were said to be oversimplified, to entail consequences not stated, to exclude other possible courses of action, to be leading toward one or the other conclusion, and to be so ambiguous as likely to lead to answers contrary to the members' real opinions. I agreed there was merit in these criticisms. I could only reply that the Special Committee and the Board of Directors had given much thought and careful study to the statement of the problem and to the form and expression of the question and that while each of us knew he could have done it better, it was the best we could agree on without more delay. I frequently added the gratuitous comment that it seemed to be characteristic of engineers to strive for perfection in these matters and so miss the opportunity for timely and effective action and that perhaps it was for this reason that we had not done more, as a profession, in the field of our nontechnical interests.

I assured the questioners that their Board of Directors had nothing to sell but were trying their best as amateur pollsters to ascertain from the broadest possible sampling of membership opinion whether or not to embark upon an expansion of the Institute's own activities in a field other than straight electrical engineering technology in a period prior to possible unification of the profession.

**President Fairman polls Amarillo**

In response to specific questions and in the light of the background of Board and Committee discussions I interpreted the two propositions (*EE, Oct '49, p 829*) in the following fashion.

### NO DANGER OF ISOLATIONISM

*Question:* Will a vote in favor of adhering to the technical field be interpreted as lack of interest in the nontechnical field or as opposition to the Institute promoting the development of a suitable organization for work in that field?

*Answer:* No. As evidenced in these meetings there seems to be no question that the members of the Institute are interested in that field

of activity. As a result of the survey of membership opinion on organization of the engineering profession conducted by the Professional Activities Subcommittee in 1946, the Board of Directors has been promoting and will continue to work for the establishment of a suitable organization of the engineering profession for handling the social, economic, and political problems of the profession (*EE, Sept '49, p 749*).

**A vote in favor of this proposition will be interpreted simply as opposed to the Institute expanding its own committee structure and staff to handle such problems in the interim.**

*Question:* If the verdict is in favor of adhering to the technical field, will the Institute discontinue existing co-operative activities with other engineering societies and become isolationist?

*Answer:* No. This is answered in part in the preceding question. Also, please note that many existing co-operative activities are in what our Special Committee has defined as the technical field and the Institute will continue as an active participant in these (*EE, Oct '49, p 890*).

*Question:* If the verdict is in favor of expanding into the nontechnological fields, will the Institute handle such problems independently and thus become isolationist?

*Answer:* No. There is ample experience to prove that separate organizations of engineers interested in the same problems must work together if they are to obtain the results they desire. If the members of the Institute favor an expansion of the committee and staff organization of the Institute to handle nontechnical problems, our new committees and staff will necessarily have to work with similar groups of other engineering societies.

### A BLANK CHECK?

*Question:* If we vote for expansion into the nontechnical field "with substantially increased dues," aren't we giving the Board a blank check?

*Answer:* No. You are merely giving the Board an expression of your desire that they proceed to undertake the preparation of plans for expansion of the Institute's own organization and to estimate the costs. No work has been done along these lines and it does not seem worth while to do it unless that is what the members want. It is probable that some organization changes would require amending the Institute's constitution. **Certainly any change in the dues would require an amendment. Hence, the membership would have one or more opportunities to vote for or against specific proposals.**

*Question:* What do you mean by "substantially increased dues"?

*Answer:* The phrase "with substantially increased dues" was added as a reminder that we can't get something for nothing. From such limited experience as we have had with our excursions into the nontechnical field, we believe that any sustained and worth-while program will involve a "substantial" increase in dues. Obviously, the amount can not be estimated until we have some idea of what the program might be and what expansion of organization and staff would be required to carry on the program.

### ORGANIZATION CHANGES

*Question:* What organization changes do you visualize as necessary to carry on work in the nontechnical field?

*Answer:* I can only speculate about that. No real consideration has been given the matter. I would expect that the changes would evolve and the structure would grow somewhat as our organization for handling our technical activities has evolved and grown. One committee's field expands to such an extent that it becomes desirable to divide its work among two or more new committees. Each of two committees has a subcommittee whose fields meet and gradually overlap. This leads to a joint subcommittee which may in due course attain the status of a main committee. Committees come into being as new problems arise. If the problem continues, the special committee appointed initially is likely to be replaced by a standing committee. As the number of committees increases, the headquarters staff to service them increases. In the nontechnical field, it seems likely that our committees and staff would need to retain the services of legal, public relations, industrial relations, and other expert counsel. As in the case of our technical activities, I would expect that we would undertake projects in which our members were interested and willing to support.

*Question:* How would the Board of Directors know the views of the membership on nontechnical problems?

*Answer:* We should need a better means of communication then we have at present. I think you will agree that the way we are trying to find out in the present instance is pretty clumsy. Just speculating again, one method would be some sort of a congress or house of delegates to which the Sections would elect representatives, presumably in proportion to their membership. It might be something like the meeting of officers and Sections delegates held annually at our Summer General Meeting. Probably it would have to meet more frequently and hold longer sessions if it were to debate and determine policies and programs to be carried out by the board or the staff or the committees. Conceivably, the travelling expenses of the delegates might have to be paid by the Institute. Again, I believe this piece of an organizational structure would evolve from a need shown by experience rather than be set up initially on purely theoretical grounds.

### WHAT WE WANT

The foregoing by no means exhausts the subject but I hope not to exhaust the reader. May I repeat—neither your Board of Directors nor your president is trying to sell you anything. **We are seeking your opinion as to whether the Institute should confine itself to technology or begin to expand to handle work in the nontechnical field while, in either event, it continues to work with other engineering societies toward a mutually satisfactory solution to the problem of over-all organization of the engineering profession.** We want a reasonably clear answer from a substantial majority of the membership. We regret our lack of skill in handling the inquiry. It's a tough problem, any way you look at it. Won't you give us a hand?

# Vibrating Reed Selective Signaling System

HAROLD M. PRUDEN    DANIEL F. HOTH

IN MANY mobile radio systems now in service, the car is provided with a loud-speaker which is in operation at all times, the desired car being called by voice. Such an arrangement has the disadvantage that the occupants of all the telephone-equipped cars hear all conversations on their channel. However, all Bell System common carrier mobile telephone systems use selective signaling arrangements which enable the mobile service operator to ring a bell in the desired car by dialing the car's telephone number.

A new selective signaling system, employing vibrating reed selectors, has been developed and is now on trial. This system is an improvement over the previous system because of its large number of code combinations (10,000), and because of the smaller size, smaller power consumption, and lower cost of the mobile signal-receiving equipment. A high degree of reliability is attained because the 4-tone calling signal employed can be transmitted continuously for a period sufficiently long to produce a signal, even under conditions of interference and fading. In contrast, signaling systems which depend on the transmission of a sequence of tone pulses may be subject to failure or possible false operation whenever a pulse is mutilated or lost due to poor transmission conditions.

The new signaling system makes use of 32 frequencies spaced 15 cycles per second apart between 352.5 and 832.5 cycles per second. Four of these tones are transmitted simultaneously by the land station to signal a particular car. The mobile receiving circuit is equipped with four vibrating reed selectors which are energized when the proper tones are received, causing the bell to ring.

At the land station, the signaling tones are generated by means of a 1,920-cycle-per-second crystal oscillator and electronic frequency divider which produce a 7.5-cycle-per-second square wave containing harmonics at all of the required frequencies. The harmonics are separated by 32 sharply tuned filters as shown in Figure 1. These filters employ vibrating reed selectors without contacts. The selectors are connected in bridge circuits, each of which is well balanced to all frequencies in the signaling band except the frequency at which its reed vibrates. The motional impedance of the selector unbalances the bridge circuit and permits transmission of its critical frequency to the register-translator relays.

Pulses from a mobile service operator's dial control the counting relays which, in turn, operate the proper register-translator relays in accordance with the number dialed. The contacts of the register-translator relays are connected to form two networks. The first network selects two frequencies from the 16 frequencies between 352.5 and 577.5 cycles per second as a result of registering the first two digits, and the second network selects two frequencies from the other 16 frequencies as a result of registering the last two digits. Each of the four tones selected for a particular calling code is connected through a regulating amplifier to a group of combining coils and thence to the input of the land transmitter.

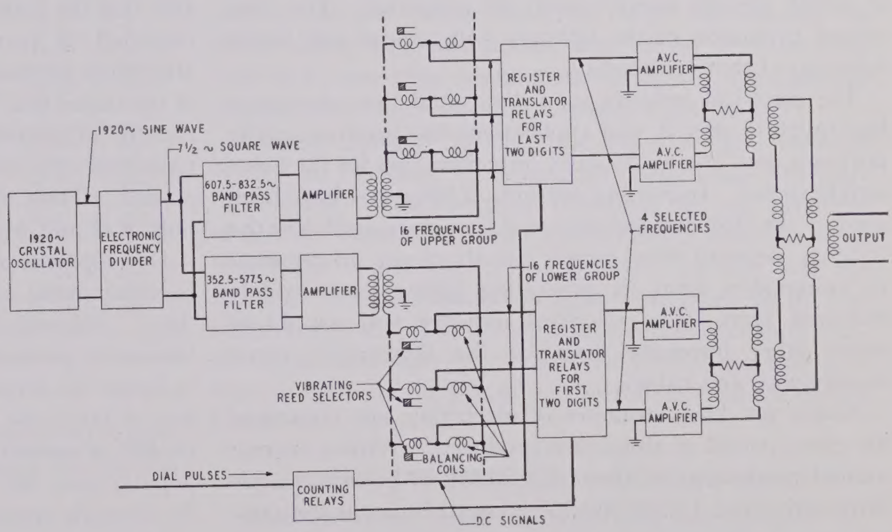


**Figure 1. Selective-signal-sending circuits at the land station**

The mobile selective signal-receiving equipment works as follows: Each station contains a group of four vibrating reed selectors equipped with contacts. When all four selectors vibrate and their contacts close, a voltage is applied to a d-c amplifier tube which operates a relay in its plate circuit to ring the call bell. The d-c amplifier is used to insure maximum selector-contact reliability by permitting the current through the contacts to be kept small.

The contact closure of the selectors is not continuous but occurs over a short part of each cycle of vibration. The closure does not necessarily occur simultaneously in all four contacts. Therefore, a network consisting of several capacitors and resistors is used to maintain a potential on the grid of the tube when all the selectors are vibrating.

Digest of paper **49-100**, "Vibrating Reed Selective Signaling System for Mobile Telephone Use," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Aluminum and the Electrical Industry

DONALD M. WHITE

**New uses for aluminum in the electrical industry are developing almost daily, while, conversely, there is increasing need for electric energy in the aluminum industry to produce the metal. Thus, the close relationship that has grown up between the two industries over the years should become even closer in the future.**

ALUMINUM holds a twofold interest for electrical engineers and the electrical industry. First, electric energy is an essential ingredient of the metal, representing some 20 per cent of its total cost. Second, aluminum is an important engineering material having large-scale applications in the electrical industry.

The electrical and aluminum industries had their beginnings at about the same time, and a close interdependence between them has grown up over the years. The aluminum industry, ever since its establishment in 1888, has been dependent on electric power for the production of the metal. One of the most important factors in the large-scale growth of the aluminum industry has been the lower and lower cost at which electric energy could be produced. The continued expansion of the industry will require still larger amounts of that commodity.

The electrical industry soon discovered that aluminum had much to offer it, and applications for current-carrying purposes were among the early important uses for the lightweight metal. Increasing amounts of the metal have been used by the electrical industry in this manner until now the industry depends very largely on aluminum to transmit its commodity from its generating plants to its widely scattered users. The electrical industry also has found many other important uses for the lightweight metal besides wire and cable.

About ten kilowatt-hours of electricity are consumed for every pound of aluminum produced. With a current annual production of about 1,250,000,000 pounds, simple arithmetic gives 12,500,000,000 kilowatt-hours as the present annual consumption of the primary aluminum industry in the United States.

Most of this energy is used in the electrolytic reduction of the metal from its oxide, only a small percentage being required for driving mechanical equipment and for the lighting, heating, and control functions common to the majority of industrial plants. As the production of aluminum is a 24-hour-a-day 7-day-a-week operation, aluminum reduction plants have a load factor of almost 100 per cent.

Aluminum's large-scale application in electric wire and cable stems largely from its high electrical conductivity which on a volume basis is about 61 per cent of that of copper, but on a weight basis is more than twice that of copper. In addition, the light weight, high resistance to corrosion, workability, and other attractive characteristics of aluminum have led to the same sort of applications in electric machinery, equipment, and appliances that are found in other fields.

It is estimated that there are now more than 4,000 uses for aluminum, and the metal is a basic raw material for more than 17,000 businesses in the United States employing approximately a million people. Many of these uses have developed since World War II, and the list is still growing.

Some postwar applications began as substitutions for materials that were scarce and high-priced during the immediate postwar years. Aluminum is so highly adaptable that the majority of these substitutions soon came to be regarded as permanent. As a result, the demand for aluminum increased to such an extent that the large surplus of the metal that had been predicted for the postwar years rapidly developed into a scarcity which continued for some time after shortages of many other materials no longer existed. Thus, aluminum today is a strategic material in both war and peace.

Development of aluminum to the full stature of a major, essential metal has come about in a spectacularly short time. Although the French chemist Sainte-Claire Deville labored to produce enough aluminum at a low enough cost to equip the armies of Napoleon III, the best he could do was to bring the price down from $545 a pound in 1852 to $17 a pound by 1859. This price scarcely invited popular use, but it did make the metal more available for scientific research.

Aluminum was a real challenge to the scientific world. It is the third most abundant of elements and it comprises about eight per cent of the earth's crust, but it is found only in combination with other elements. How to extract it at a commercially practical cost was the problem.

Finally, in 1886, Charles Martin Hall, who had just been graduated from Oberlin College, developed the electrolytic process by which aluminum oxide, or alumina, could be reduced to metallic aluminum at a fraction of the cost of previous methods. Within two years, in 1888, The Pittsburgh Reduction Company was organized and the aluminum industry was born.

## PARALLEL GROWTH OF ALUMINUM AND ELECTRICAL INDUSTRIES

Growth of the aluminum industry is best illustrated by its production statistics (Table I). Beginning with about

Essentially full text of paper **49-250**, "Aluminum and the Electrical Industry," recommended by the AIEE Committee on Mining and Metal Industry and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cincinnati, Ohio, October 17–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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**Table I. Aluminum Output and Price**

*(From American Metal Market)*

| Year | Production, Short Tons | Approximate Annual Range in Price Per Pound of 98–99 Per Cent Aluminum in New York |
|---|---|---|
| 1883–92 | 280 | $8.00 (1888) |
| 1893#–02# | 13,701 | $2.00 (1889) |
| | | Cents |
| 1903# | 3,318 | 31.00—33.00 |
| 1904# | 4,050 | 30.00—32.00 |
| 1905# | 5,405 | 33.00—35.00 |
| 1906 | 9,796 | 35.00—38.00 |
| 1907 | 8,162 | 36.00—50.00 |
| 1908 | 5,339 | 22.00—34.00 |
| 1909 | 14,540 | 22.00—24.00 |
| 1910 | 17,701 | 22.00—24.00 |
| 1911 | 19,198 | 18.50—22.50 |
| 1912 | 20,903 | 18.75—27.12½ |
| 1913 | 23,639 | 18.50—27.12½ |
| 1914 | 28,986 | 17.37½—21.50 |
| 1915 | 45,252 | 18.75—60.00* |
| 1916 | 57,553 | 53.00—67.00* |
| 1917 | 64,930 | 35.00—64.00* |
| 1918 | 62,362 | 32.00—33.00 |
| 1919 | 64,238 | 29.00—33 00 |
| 1920 | 69,021 | 22 00—32.75 |
| 1921 | 27,266 | 17 00—26.00 |
| 1922 | 36,816 | 16.50—23.00 |
| 1923 | 64,329 | 22.50—27.75 |
| 1924 | 75,282 | 26.00—28.00 |
| 1925 | 70,058 | 27.00—28.00 |
| 1926 | 73,693 | 26.50—27.00 |
| 1927 | 81,803 | 23.90—27.00 |
| 1928 | 105,272 | 23.90—23.90 |
| 1929 | 113,986 | 23.90—23.90 |
| 1930 | 114,518 | 22.90—23.90 |
| 1931 | 88,772 | 22.90—22.90 |
| 1932 | 52,444 | 22.90—22.90 |
| 1933 | 42,562 | 22.90—22.90 |
| 1934 | 37,088 | 19.00—23.30† |
| 1935 | 59,647 | 19.00—22.00† |
| 1936 | 112,464 | 19.00—22.00† |
| 1937 | 146,340 | 19.00—22.00† |
| 1938 | 143,441 | 20.00—20.00† |
| 1939 | 163,545 | 20.00—20.00† |
| 1940 | 206,280 | 17.00—20.00† |
| 1941[a] | 309,067 | 15.00—17.00† |
| 1942 | 521,106 | 15.00—15.00†** |
| 1943 | 920,179 | 15.00—15.00† |
| 1944 | 776,446 | 15.00—15.00† |
| 1945 | 496,487 | 15.00—15.00† |
| 1946[a] | 409,630 | 15 00—15.00† |
| 1947 | 571,750 | 15.00—15.00† |
| 1948 | 622,179 | 15.00—17.00† |

[a] Reynolds started ingot production on May 31, 1941; the Kaiser unit (Permanente) in the autumn of 1946.

# Years ending August 31.

* During 1915, 1916, and 1917, the Aluminum Company of America sold consumers on annual contracts at much lower than the open market prices. The averages of these contract prices are estimated at 32.00 cents in 1915, 34.00 cents in 1916, and 37.00 cents in 1917.

† 99 + per cent virgin ingot.

** On December 5 the Aluminum Company of America announced a price of 14.00 cents per pound for aluminum in pig form, average guaranteed minimum 99 per cent.

50 pounds in 1888, the daily production mounted to a peak of more than 5,000,000 pounds during World War II. Although some of the plants built during the war are no longer in operation, today's production still averages about 3,500,000 pounds a day. This is more than four times the daily production in 1939.

History and growth of the aluminum industry have closely paralleled those of the electrical industry. In fact, as already pointed out, the great technological achievements of the electrical industry have played a significant role in the progress of the aluminum industry. Electrical progress has brought cheaper electric power; cheaper power has meant cheaper aluminum; and cheaper aluminum has led to new uses and a mounting demand for the metal.

Production of aluminum remained small for several years after operations began in 1888, even though reductions in price from $5 a pound to less than a dollar a pound were effected during that period. In spite of the small demand in the beginning, however, the output of the initial plant soon became inadequate, and new plants therefore were built.

As production in large quantities really got under way after 1900, larger and larger plants were built to meet the increasing demands. Refinements were added from time to time which increased the efficiency of the process. These factors, together with the steadily decreasing cost of electric energy led to a progressive lowering of the price of the metal, as indicated by Table I.

To meet the prodigious demands of World War II, new plants were built which greatly expanded the aluminum industry's capacity. As may be noted from Table I, peak production was reached in 1943 when the industry turned out a total of more than 1,840,000,000 pounds.

Because of the scarcity of electric power in most areas during the war, some of the plants built then were erected in localities where power costs were relatively high. The metal had to be produced regardless of cost, so the plants were built wherever power at any price was available. These plants produced a lot of badly needed metal for war uses; but they obviously could not compete with plants having cheaper power available. For this reason, the plants using high-cost power were closed after the war and have now been dismantled. However, the industry still has about four times the capacity it had in 1939.

Effective January 1, 1907, the name of the Pittsburgh Reduction Company was changed to Aluminum Company of America. This company remained the sole producer of primary aluminum in the United States from the early beginnings of the industry until 1941. In that year the Reynolds Metals Company began operations in its first reduction plant. The Kaiser-controlled Permanente Metals Corporation entered the field in 1946, beginning production in one of the plants built by the government during World War II.

## ALUMINUM PRODUCED IN THREE STEPS

Although many types of aluminum-bearing ores are found widely distributed throughout the world, practically all the aluminum being produced commercially today comes from one ore—bauxite. This ore contains from 50 to 60 per cent alumina, 25 to 32 per cent water chemically combined with the alumina to form a hydrated oxide, 2 to 14 per cent silicon oxide, 2 to 10 per cent iron oxide, and 2 to 3 per cent titanium oxide.

Three distinct basic operations are involved in the production of aluminum: mining of the ore and delivery to processing plants; production of alumina from the ore; and the reduction of alumina to metallic aluminum.

Mining of bauxite is carried out by standard methods, after which the ore is washed, crushed, and dried. It is then ready to be transported to the alumina plant for the second of the three basic operations. This may involve shipment over long distances, particularly for ores imported from other countries.

Several processes have been developed for refining bauxite, but the one most commonly used is the Bayer process invented by the German chemist, Karl Josef Bayer, and first patented by him in 1888. The crushed, washed, and dried bauxite from the mines is pulverized, mixed with a hot solution of sodium hydroxide, or caustic soda, and pumped into large pressure tanks, called digesters. In these digesters the sodium hydroxide dissolves the hydrated aluminum oxide out of the bauxite leaving the impurities in solid form. The mixture next is passed through filter presses to separate the solid impurities called "red mud," and the filtered solution is pumped into large precipitating tanks. As the solution cools in these tanks, the hydrated aluminum oxide crystallizes, or precipitates, out of the solution, and the remaining sodium hydroxide solution is reused in the process. The precipitated hydrated oxide is then washed and calcined (heated to white heat), which removes the chemically combined water, leaving essentially pure aluminum oxide, or alumina.

During World War II a process came into use for treating low-grade ores high in silica content. In this combination process, the low-grade bauxite is treated by the Bayer process, alumina and soda equivalent to the silica content of the bauxite being lost in the red mud. However, instead of being discarded, the red mud is sintered with soda ash and limestone. The sinter is leached with water and the dissolved alumina and soda are returned to the process to be digested with bauxite and caustic. This process has made available substantial tonnages of bauxite not previously considered suitable as a source of alumina.

Carbon-lined steel electrolytic cells are employed in the reduction of alumina during the third step of the 3-step process. The current (direct) is introduced into the cell through carbon electrodes suspended on rods from a bus bar above, the carbon cell lining serving as the cathode. In operation, cryolite first is introduced into the cell. After it has been fused by the heating action of the electric current, the alumina is added, dissolving in the molten cryolite. As current passes through the solution, the alumina is separated into its constituents, aluminum and oxygen. The aluminum settles to the bottom of the cell in molten form and is drawn off at appropriate intervals. The oxygen combines with the carbon of the electrodes, forming carbon dioxide and consuming the electrodes in the process.

As the aluminum comes from the cells it contains some dross and some bath material. Remelting to remove these nonmetallic impurities usually is necessary before pig aluminum can be used in fabricating aluminum products. Where alloying elements are to be added, they can be introduced during the same operation.

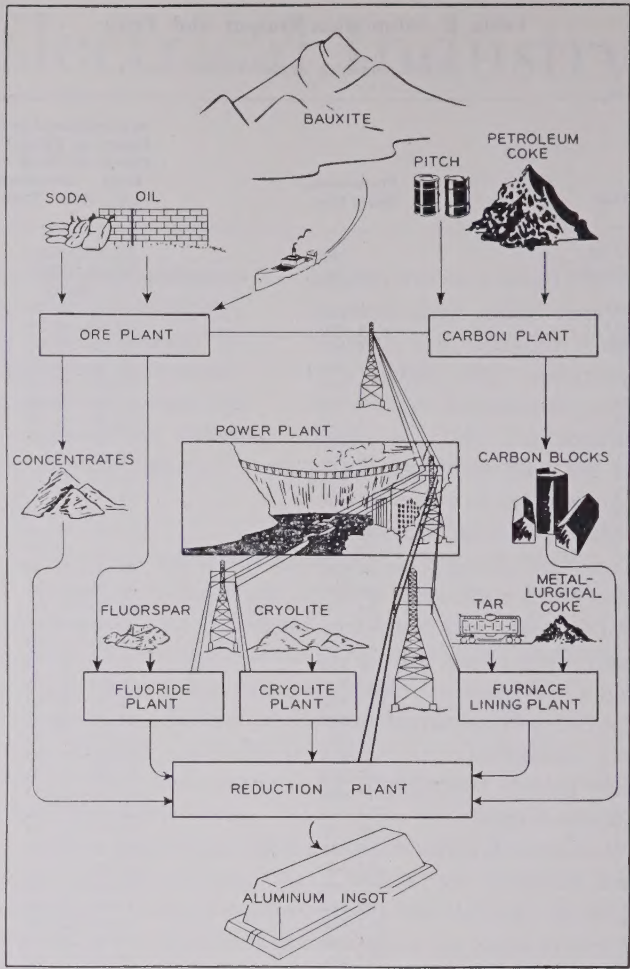


**Figure 1. Flow diagram showing essential part that electric energy plays in production of aluminum ingot**

*From Canadian Geographical Journal, November 1938*

From four to six pounds of bauxite are required to produce two pounds of alumina (Table II). To reduce this to one pound of aluminum requires ten kilowatt-hours of electric energy, and three-quarters of a pound of carbon electrode is consumed in the process.

**Table II. Materials Required for a Ton of Aluminum**

| | |
|---|---|
| To produce 2,000 pounds of primary aluminum requires: | |
| Alumina | 4,000 pounds |
| Carbon paste | 1,300 pounds |
| Cryolite | 60 pounds |
| Aluminum fluoride | 80 pounds |
| Electric energy | 20,000 kilowatt-hours |
| Labor | 30 man-hours |
| To produce the 4,000 pounds of alumina needed for 2,000 pounds of primary aluminum requires: | |
| Bauxite | 8,000 pounds |
| Quick lime | 240–360 pounds |
| Soda ash | 280–400 pounds |
| Coal | 2,400–3,200 pounds |
| (or 20,000–26,000 cubic feet natural gas) | |
| Labor | 10–12 man-hours |

## ELECTRIC EQUIPMENT IN ALUMINUM REDUCTION PLANTS

Electric power for the initial plant of the Pittsburgh Reduction Company was supplied by two Edison bipolar d-c generators, each rated 1,000 amperes at 25 volts. They were driven by a single 125-horsepower steam engine, and steam was produced in two gas-fired boilers.

When the initial plant was enlarged in 1890, two generators having a capacity of 2,500 amperes at 50 volts were installed. Steam-driven d-c generators also furnished power for the initial New Kensington, Pa., works, which was built in 1895. This early equipment stands in sharp

contrast to the extensive electrical installations found in today's huge reduction plants.

When production shifted to Niagara Falls in 1895 the first contract for power from that development called for 1,500 horsepower initially, with an option for an additional 1,000 horsepower. From that time until World War II, all aluminum reduction plants were built near large hydroelectric developments. One of the plants built during the war was supplied by diesel-engine-driven generators. Since the war, this plant, at Jones Mills, Ark., has been operated by the Reynolds Metals Company. A new plant now being built at Point Comfort, Tex., by the Aluminum Company of America will have d-c generators driven by spark-fired engines utilizing natural gas from off-shore oil fields.

Adoption of the a-c system at Niagara Falls marked the final emergence of that system over the d-c system as the one best adapted to large-scale electric power development. For the aluminum industry, it meant that some means must be provided for converting alternating current to the direct current required in the electrolytic process. At Niagara Falls and in other plants for many years thereafter this was accomplished by means of synchronous converters. In a few instances, motor-generator sets were installed. All large installations of conversion equipment since about 1936 have been mercury-arc rectifiers.

Pot lines have grown enormously since the early days. Not only are the individual pots themselves much larger, but more pots are used in series on a pot line. The original Smallman Street pots required a current of 1,700 to 1,800 amperes at 16 volts. Modern pots use up to 50,000 amperes, and groups up to 120 are connected in series for operation at 600 volts. Refinements in the process and advances in pot design and construction have been such that a voltage of only 5 to 7 volts now is required per pot. The amount of energy required per pound of metal also has been reduced. For example, about 14 kilowatt-hours per pound was the consumption rate in 1926; the newest plants today produce the metal at a rate of less than 10 kilowatt-hours per pound.

### ALLOYS USEFUL IN ELECTRICAL INDUSTRY

Because pure aluminum has higher electrical conductivity than its alloys, the metal is used almost entirely in its commercially pure form for electric conductor wire and cable and many current-carrying parts. Galvanized high carbon steel wire is combined with aluminum wires to form high strength conductors known as aluminum conductor steel reinforced (ACSR).

For many current-carrying parts, alloys of carefully controlled composition containing small amounts of other elements normally are used to obtain better mechanical characteristics. Larger proportions of alloying constituents are added where high strength, improved fabricating qualities, or special characteristics are required. Still higher strength, improved mechanical characteristics, or both, can be developed in some alloys by heat treatment.

Out of the large number of elements that can be alloyed with aluminum, practical considerations have limited them to comparatively few in present commercial alloys. These are principally copper, silicon, magnesium, zinc, and nickel, and to a lesser extent manganese, chromium, titanium, and tin.

Copper and silicon are added by far the most often and with few exceptions in the largest proportions. Zinc has been used to a considerable extent in Europe because of its lower cost, but has had more limited use in the United States. Nickel is used chiefly in complex alloys to aid in retaining mechanical properties at elevated temperatures. Magnesium has come into more common use in recent years as improved methods of producing and handling these alloys have brought lower cost. In fact, some of the highest-strength aluminum alloys are those containing this extremely light metal.

The remaining alloying elements are added for special purposes where special characteristics are required and, in general, are used in small but carefully controlled proportions. Iron is one of the impurities in commercial aluminum, and in only a very few alloys is any iron intentionally added.

### PHYSICAL AND MECHANICAL PROPERTIES

Pure aluminum has a specific gravity of 2.70. The specific gravity of the various alloys varies but little from this value, and for practical purposes all aluminum alloys may be considered to weigh about 0.1 pound per cubic inch.

Aluminum of so-called "electric conductor" grade (99.45 per cent pure) has an electrical conductivity of about 61 per cent of that of the International Annealed Copper Standard, and a thermal conductivity of about 0.53 in centimeter-gram-second units at a temperature of 25 degrees centigrade. Both properties have lower values in the alloys, the former ranging down to about 21 per cent and the latter to about 0.21 in centimeter-gram-second units.

For all alloys the modulus of elasticity is approximately 10,300,000 pounds per square inch; the modulus of rigidity, 3,850,000 pounds per square inch; and Poisson's ratio, 0.33.

Mechanical characteristics of both wrought and cast aluminum products depend partly upon the method of

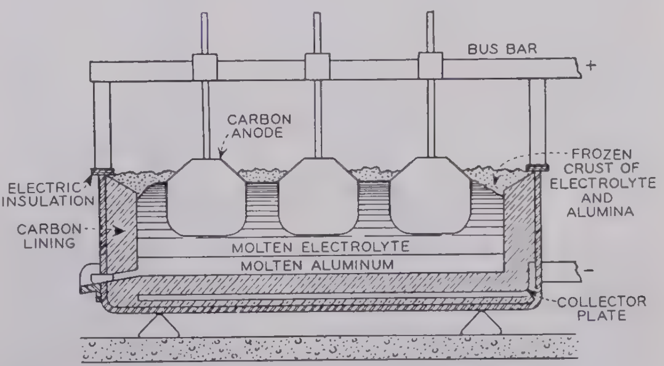


**Figure 2. Cross-sectional diagram of electrolytic cell for production of aluminum from alumina**

*From "Aluminum and Its Applications" by Hiram Brown, Pitman Publishing Corporation, 1948*

fabrication. Aluminum is hardened by mechanical working, particularly cold working, and sheet, plate, and strip are available in a variety of tempers. The final characteristics in a given wrought part, however, will depend quite largely upon the amount and nature of cold working the metal receives during fabrication.

Likewise, the mechanical characteristics of cast parts vary somewhat with the casting method used. Strength and hardness of the metal vary with the rapidity with which the poured metal is chilled, and, therefore, castings produced in metal molds are stronger and harder than sand castings.

Commercially pure aluminum has a tensile strength of about 13,000 pounds per square inch, a yield strength of about 5,000 pounds per square inch, and an elongation of 45 per cent. Tensile strength can be raised by cold working to about 24,000 pounds per square inch, with yield strength of about 21,000 pounds per square inch and elongation of 15 per cent.

Wrought alloys of the non-heat-treatable type, as those not responding to heat treatment are called, have tensile strengths up to about 62,000 pounds per square inch, with yield strength up to 58,000 pounds per square inch and elongations as low as 6 per cent. Heat-treated wrought alloys have tensile strengths as high as 89,000 pounds per square inch, with yield strength of 84,000 pounds per square inch and elongation of about 10 per cent.

Non-heat-treatable casting alloys have tensile strengths up to about 30,000 pounds per square inch, with yield strength up to 24,000 pounds per square inch and elongation of only 1.0 per cent. Heat-treated casting alloys have tensile strengths up to 50,000 pounds per square inch, with corresponding yield strength of about 36,000 pounds per square inch and elongation of less than 0.5 per cent.

**Figure 3. Rectifier room in a modern aluminum reduction plant**

Other characteristics of aluminum that have helped make the metal so useful in so many applications are high resistance to corrosion, excellent workability, and the ease with which it may be machined and finished. Aluminum's nonmagnetic and nonsparking characteristics are of particular interest to electrical engineers. The fact that it is nonmagnetic means that it is excellent for electrical shielding purposes. Its nonsparking characteristics make it particularly adaptable for uses in atmospheres containing inflammable or explosive gases or mixtures.

Aluminum also has high reflectivity to light and heat. This means that it is useful in lighting fixtures where good light-reflective characteristics are essential. Its high thermal reflectivity makes it an excellent material for thermal insulation in buildings.

Aluminum and most of its alloys can be welded successfully by most of the common methods, both gas and electric. Although the welding of this metal is somewhat different from that of other metals, procedures have been developed by which the majority of aluminum alloys may be successfully joined by this method. Either manual or automatic welding may be employed.

In gas welding, either oxyhydrogen or oxyacetylene torches ordinarily are used. In arc welding, all of the common methods are applied—metal-arc, carbon-arc, tungsten-arc, and atomic-hydrogen. Tungsten-arc welding is being found particularly useful with aluminum and is especially adaptable to automatic production setups. In this method, a special welding torch is used through which argon gas is fed to the welding area. The gas protects the molten metal from oxidation, and no flux is required.

Resistance welding of all types likewise may be applied—spot, seam, and flash. Because of the high electrical and thermal conductivities of aluminum, high-peak short-duration "shots" are required, and therefore energy-storage methods are most useful with this metal and its alloys. Both electrostatic and electromagnetic energy-storage systems are being used.

Brazing is another method of joining that is being successfully applied to some aluminum alloys. This method is especially useful in the mass production of complicated structures.

Perhaps no other commonly used metal offers as broad a range of surface finishes as aluminum. For many purposes, no special surface treatment is needed, as the metal has an attractive appearance which suffers little change under a wide variety of service conditions. Where the plain aluminum surface does not provide the desired qualities, a large number of easily applied finishes is available, ranging from the purely utilitarian to the highly decorative. They are applied by either mechanical, chemical, or electrochemical means, depending on the required surface characteristics and the desired appearance. Paint, lacquer, or enamel also may be successfully applied to aluminum.

Oxide coatings applied to aluminum surfaces by anodic treatment are perhaps the most versatile of all the various finishes available. Like electroplating, the method involves treating the parts in an electrolyte; but unlike electroplating, the parts are connected to the anode of the electric supply circuit instead of the cathode. As a result, aluminum oxide is formed on the surface of the aluminum. This oxide coating is many times thicker than that which forms naturally on exposure to the atmosphere and is also integral with the surface of the metal. These coatings have a hard smooth surface and are resistant to atmospheric corrosion, wear, and chemical attack. They can be impregnated with a variety of dyes or pigments to produce a variety of colors, or with corrosion inhibitors, such as the chromates, to increase the resistance to corrosion.

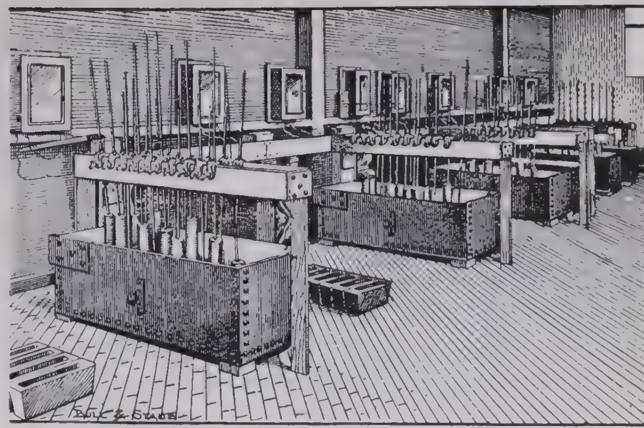

**Figure 4. Original 1888 electrolytic pot room of the Pittsburgh Reduction Company**

## APPLICATIONS IN THE ELECTRICAL INDUSTRY

An aluminum bus bar installed in 1895 in the original Niagara Falls reduction works is said to be the first application of the metal for electric-current-carrying purposes. In 1897, a half mile of number 11 aluminum telephone wire was erected in the Chicago stockyards where locomotive gases corroded copper wire within a short period of time.

The first use of aluminum transmission cable was on a 46-mile 3-phase line from Blue Lakes to Stockton, Calif., which was erected in 1898. This cable was fabricated from an alloy containing two per cent copper. Large-scale use of aluminum transmission cable did not begin, however, until some years later, after the invention of the steel-reinforced conductor, now commonly known as ACSR. The rapid growth in the use of this cable is well known to electrical engineers. It is estimated that about 80 per cent of all transmission lines erected during the past 10 or 15 years use conductors of this type.

Aluminum bus bars have come to be used quite widely. A newer use is in building wire, principally for commercial and industrial wiring purposes. Aluminum building wire is now fully recognized by the National Electrical Code and other authorities, and its use has greatly expanded during the past five years. Aluminum conduit also is being used to an increasing extent. Aluminum fittings for both wire and cable and conduit are being produced.

Aluminum foil has been used for years in the manufacture of capacitors. A newer use of thin sheet foil is in a composite aluminum-plastic sheath for telephone cable now being made for the Bell telephone system, known as Alpeth cable.

Cast aluminum rotors for induction motors is another important electrical application that is increasing in volume and is being extended to an expanding range of motor sizes. In this application the rotor bars and cooling fans are often cast in one piece. Cast aluminum end bells for motors is an application that grew up during the war and expanded during the postwar shortages of other metals.

Both current-carrying and non-current-carrying parts of relays and circuit breakers are being made of aluminum. In these units, the light weight of the metal contributes toward higher operating speeds, which is an important consideration in many cases. The same considerations have led to the use of aluminum in the electrode arms of spot-welding machines. Die-cast aluminum meter cases are being produced in large numbers.

Aluminum's nonmagnetic characteristics have led to its extensive use for electrical shielding purposes. An interesting wartime application was aluminum cases for radar and other electronic equipment. As a result of this successful application, some radio manufacturers are now building sets with aluminum chassis. A recent striking application in the radio field is aluminum-finned cooling radiators for radio transmitting tubes. Large reductions in weight were effected here, which means that in some instances tubes that formerly required two men to handle can now be handled by one man.

One of the most diversified fields of application for aluminum is that of household electric appliances where aluminum parts are found as major components of vacuum cleaners, mixers, washing machines, sewing machines, refrigerators, electric irons and hotplates, ironers, and many others. Light weight, resistance to corrosion, and attractive appearance are all important factors in these appliances; high thermal conductivity also is important in electric irons and other units where the question of heat distribution is involved.

Outdoor transmission and substation structures represent another application which has attractive possibilities. Generating station and substation buildings also are utilizing substantial quantities of aluminum. This is in conformity to the present strong trend toward increased architectural usage of the metal, which now ranks first among the various classes of application.

Many more applications of interest to electrical engineers could be cited, but enough have been mentioned to demonstrate clearly the importance of the metal to the electrical industry. New uses are developing for this most modern engineering and construction material almost daily, and many of these are in the electrical field or in closely allied industries. As the use of aluminum continues to expand, more and more electric energy will be required to produce the metal. Thus the close relationship that has grown up between the two industries through the years seems destined to become even closer in the future.

# Stabilizing a Wide-Band D-C Amplifier

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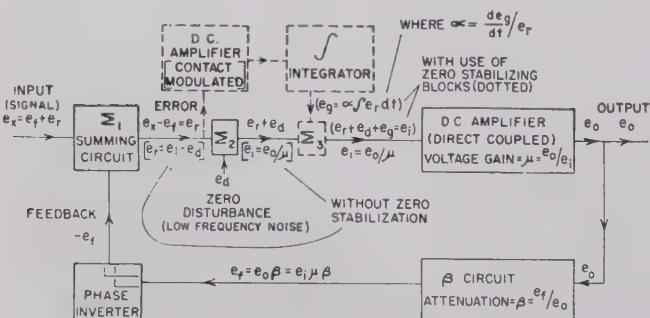
ALMOST any electron tube is fundamentally a d-c amplifier having a wide frequency-pass band, but it inherently is not immune to changes in supply voltage, cathode temperature, and so forth.[1,2] A sufficiently stable gain (incremental) generally can be obtained by the use of negative feedback.[3]

A sufficiently stable "zero" (zero output for zero input) is more elusive, bringing into use such aids as stabilized "B" supply, balanced or bridge arrangement of tubes, stabilized heater supply, and adjustable compensation for changes in supply voltage (or for changes in thermionic emission).[4]

Because of these zero-stabilization difficulties with direct-coupled d-c amplifiers, contact-modulated d-c amplifiers (with zero stable to a fraction of a microvolt)[5] have been found useful in spite of their relatively narrow pass band, which is generally only a fraction of the modulation frequency. The problem has been to devise an amplifier fulfilling two requirements: the wide band of the direct-coupled d-c amplifier; and the stable zero of the contact-modulated d-c amplifier.

In a simple direct-coupled d-c amplifier, the presence of zero drift cannot be detected without temporarily taking the amplifier out of service, as by short-circuiting the input and observing whether the output is zero. However, in a direct-coupled d-c amplifier with gain stabilized to a considerable degree (as by negative feedback), a comparison of input, with output divided by gain, tells of the presence or absence of zero disturbance at any and all times, with or without signal. The zero stabilization is made on the basis of this comparison.

Figure 1 gives the system in block form showing the feedback loop and showing the zero disturbance as the voltage $e_d$. Equations 1 to 5 show that, without zero stabilization, $e_d$ introduces an error which cannot be reduced by increase of gain, $\mu$. The zero stabilization blocks (shown dotted) continuously work toward the reduction of this error. They are effective because of the inherent zero stability of the contact-modulated d-c amplifier previously mentioned[5] and because of the theoretically unlimited correcting voltage, $e_g$, which can be applied by the integrator, if necessary.




WITH OR WITHOUT ZERO STABILIZATION

$$\text{INPUT} = \text{FEEDBACK} + \text{ERROR} \qquad (1)$$
$$e_x = e_f + e_r \qquad (2)$$
$$e_x = e_o\beta + e_r \qquad (3)$$

WITHOUT ZERO STABILIZATION

$$e_x = e_o\beta + e_i - e_d \qquad (4)$$
$$e_x = e_o\beta + e_o/\mu - e_d \qquad (5)$$

WITH ZERO STABILIZATION AND AFTER VOLTAGES BECOME CONSTANT

$$e_x = e_o\beta \qquad (6)$$

**Figure 1. Direct-coupled d-c amplifier stabilized for gain and for zero**

*The contact-modulated d-c amplifier and integrator stabilize the zero*

From the relations given in the illustration, a differential equation can be set up for the stabilized case, and, for prescribed time forms for $e_d$, the error can be calculated. With a slowly changing value of $e_d$ (and with appropriate constants), the error is at all times very small.

An experimental amplifier was assembled from two items which were on hand, namely: a contact-modulated d-c amplifier;[5] and a direct-coupled d-c amplifier.

With an abrupt change of input voltage the output response was complete in less than 0.005 second, as observed on a cathode-ray oscillogram. This response was essentially the same as that of the direct-coupled amplifier and approximately 200 times faster than that of the contact-modulated amplifier, thus fulfilling the first of the two requirements (wide band).

Since changes of cathode temperature produce zero disturbances, the heater voltage of one of the balanced input tubes of the direct-coupled d-c amplifier was varied at the rate of 20 per cent per minute in the range ±10 per cent from the rated value. The output effect, referred to the input, amounted to less than 0.001 volt. Without zero stabilization, the same changes in heater voltage produced an effect, referred to the input, of 0.300 volt. The factor of improvement, therefore, is about 300 for this type of zero disturbance. Thus, the second of the two requirements (stable zero) appears to have been fulfilled by the exploratory experimental amplifier.

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Digest of paper **49-132,** "Wide-Band D-C Amplifier Stabilized for Gain and for Zero," recommended by the AIEE Joint Subcommittee on Electronic Instruments and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Design of Transformer Manholes and Vaults

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SECONDARY network systems serving a distributed load, without substantial concentrations of power, generally are supplied from individual transformer installations strategically located for maximum economy in distribution. Such single-transformer installations are commonly located in the roadway where they may be subjected to flooding and hence submersible equipment is used. These manhole units are connected to the network mains and usually have no customer service connection. On the other hand, where substantial concentrations of load occur, say in the order of 200 kva or more, transformer installations adjacent to the customer's service point are indicated. These vault installations provide for a customer's service connection and have a secondary tie to the street network. The number of banks required in a multiple-bank installation will be determined by the customer's maximum demand, the size of transformer used, the design of the secondary network system, and the permissible loading of the transformers under emergency conditions.

Adequately designed transformer manholes and vaults will provide: ventilation adequate for optimum utilization of the transformer and network protector; direct and immediate access for maintenance crews 24 hours per day; arrangement of transformers in multibank installations to provide approximately equal division of load; isolation of equipment so as to confine any fire or explosion to the equipment where the trouble occurs so that service will not be interrupted; minimum size of manhole or vault compatible with installation and maintenance; and adequate drainage.

Natural ventilation is essential for a maximum degree of reliability. Roof gratings or wall openings, close to the transformers and ventilating directly to the outside atmosphere without the use of horizontal ducts, generally give the best results. The National Electric Code requirement of two square feet per 100 kva of installed transformer capacity provides adequate ventilation, where the gratings are directly over or close to the transformers in most cases of cyclic loading where the 24-hour average outside ambient temperature does not exceed 30 degrees centigrade. Tests and experience indicate that 500-kva network installations, provided with a vent grating with a minimum of ten square feet (net) opening, will permit normal loading in the order of 100 per cent nominal rating when operating under an industrial load cycle with an 8-hour peak, 60 per cent load factor, and an average outside ambient temperature of 26 degrees centigrade. This loadability is based upon maximum hot-spot temperature

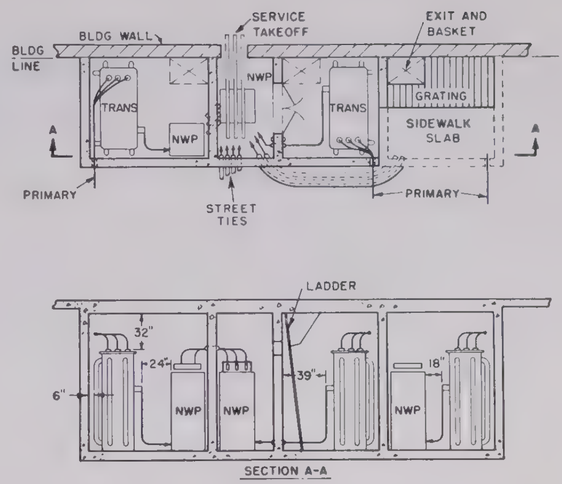


**Figure 1. Typical layout of subsidewalk vaults at building time; three 1,000-kva banks**

recommended by ASA (American Standards Association) Standard C57-32. Vault structures should be explosion-proof, for a transformer failure may fill the vault with explosive gases or a "stewing" cable fault may generate explosive gases. The amount of explosive gas accumulated will be reduced as the size of the vault is reduced and the size of the vent opening is increased. Hence the probability and severity of a vault explosion are reduced when the ratio of vault volume to net vent area is kept to a minimum.

Investigations have indicated that where this ratio of volume to vent opening does not exceed 50 to 1, an 8-inch reinforced concrete wall generally is strong enough to protect any personnel or equipment which may be outside a vault wall when the explosion occurs. These conclusions are based upon approximate probable maximum pressures which may be produced in a vault by the explosion of oil vapors. Transformer manholes and vaults are best constructed of reinforced concrete for watertightness and strength. Where subsurface conditions permit, precast concrete construction may offer some economy in construction cost, and, in traffic areas, precast construction will be of great value in reducing the period of time the street is open.

Minimum size of vault or manhole is determined by the design of the equipment and the clearances deemed necessary for installation and maintenance. Figure 1 shows working clearances that have been found satisfactory for a typical transformer vault installation.

Drainage is desirable, when submersible equipment is used, to reduce the cost of maintenance, provided it can be obtained at moderate cost. Vault-type equipment, particularly the nonenclosed network protector, must be protected at all times from flooding, and frequently the impracticability of obtaining a gravity drain will force the use of a permanently installed sump pump.

Digest of paper **49-133**, "Transformer Manholes and Vaults—Design and Ventilation," recommended by the AIEE Insulated Conductors Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Evaluation of Distance Relay Performance

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POWER swings which result in large angles between voltages at the ends of a system and faults cause distance relays to measure impedances tedious to evaluate by mathematical computation. Also the slow clearing of a fault may cause a power swing, so that there will be a combination of swing and fault conditions to analyze. This article describes a method of determining quickly what impedances all phase and ground distance relays measure during all of these fault and swing conditions. The method requires only a ruler and a protractor or a draftsman's 30-degree–60-degree–90-degree triangle, and a knowledge of the positive- and zero-sequence impedances of the system.

Figure 1*A* is an impedance diagram with resistance and reactance co-ordinates *R* and *X*. The line *AB* is a vector representing the true (positive-sequence) impedance of the protected transmission line whereon *F* is the fault location. The lines *AS* and *BL* represent the total system impedance behind the relay and beyond the protected line respectively and can be easily calculated from a knowledge of the short-circuit currents at the line terminals *A* and *B*, deducting the current that flows through the line.

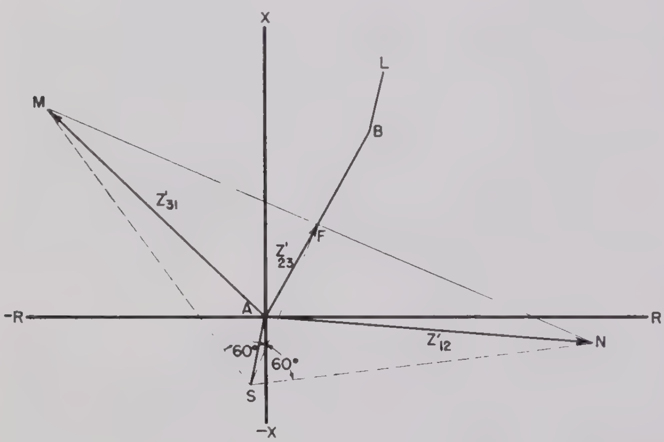


**Figure 1A. Impedances seen by phase relays for phase 2—phase 3 fault at F (nonhomogeneous line); FS = $Z_n/C$**

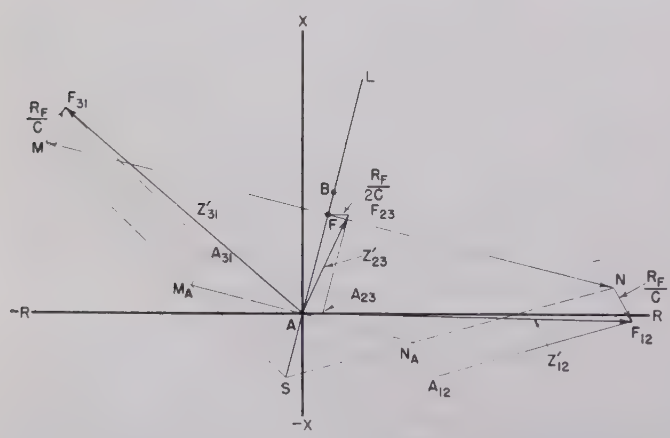


**Figure 1B. Impedances seen by phase relays for phase 2—phase 3 fault at F (homogeneous line); FS = $Z_n/C$; FM = $\sqrt{3}\,Z_n/C$; angle FSM = 60 degrees**

The impedance measured by the relay in the faulted phases *2–3* (neglecting arc resistance) is represented by the line *AF* which is the phase-to-neutral or positive-sequence impedance of the line between the relay and the fault and is referred to as the true impedance. The phase *3–1* relay sees an impedance which is leading the true impedance and the phase *1–2* relay a lagging impedance, which are obtained as follows.

Draw lines from *S*, 60 degrees on each side of *SF*, to meet perpendiculars to *SF* drawn from *F* at *M* and *N*. *AM* is the impedance seen by the *3–1* relay and *AN* the impedance seen by the *1–2* relay. The arc resistance $R_F/C$ is added at 60 degrees leading the *R* axis so that the total impedance $Z_{31}'$ seen by the phase *3–1* relay is the vector $AF_{31}$. $Z_{12}'$ is found in a similar manner, but using a 60-degree lagging shift. By drawing the perpendiculars from *A* instead of *F*, the points $M_A$ and $N_A$ can be found which give the impedances for a fault at the relay location *A*. The addition of the arc resistance locates the points $A_{31}$ and $A_{12}$ so that now four points have been located which define the fault areas. The arc resistance is expressed as $R_F/C$ instead of $R_F$ because only the fraction *C* of the fault current flows through the relay; the rest comes from the line section on the other side of the arc.

The procedure for ground relays and for the other faults is similar except that the angles at which the lines *SM* and *SN* and the arc resistance are drawn are 30 degrees instead of 60 degrees in the same cases, and an additional term $Z_0$ is added in ground faults. Power swings and faults with power swings require a different construction.

By superimposing the impedance characteristic of the relay upon such diagrams it is possible to determine quickly just what a phase or ground distance relay will do under any fault or power-swing condition. Not only does this assist in the choice of a suitable type of relay but it is useful for analyzing an erroneous operation which otherwise would be very difficult to explain. The success of the method of course depends very much upon the accuracy and consistency of the relay characteristics since the performance of the relay can be predicted only if its operation conforms with the characteristic superimposed on the diagram. Distance relays are available which stay within ±2 per cent of their advertised characteristic.

Digest of paper **49-154**, "Graphical Method for Estimating the Performance of Distance Relays During Faults and Power Swings," recommended by the AIEE Relay Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Photoeffects in Semiconductors

**As part 2 of a series of articles summarizing the material presented at a Summer General Meeting symposium on semiconductors and the transistor, this article discusses photoeffects in semiconductors. The first article in the series covered rectification.***

THE STUDY of photoeffects in semiconductors is important for two reasons. Devices using photoeffects are already employed in electrical engineering and their use is likely to increase as engineers develop and improve such devices and their characteristics become better known by apparatus and system engineers. In the second place, photoeffects give the physicist and design engineer a clearer picture of the mechanism of conduction and the processes taking place in semiconductors than do effects produced by thermal agitation. In photoeffects the scientist can deduce the effects of individual quanta of light while in thermal effects only average results are observed.

When light of sufficiently high frequency is absorbed by a semiconductor, the energy in the light quanta is transferred to electrons whose energy is increased. These activated electrons may have sufficient energy to be completely removed from the semiconductor cathode and appear in the surrounding vacuum or gas. From here they can be collected by an anode and their number and velocity distribution measured. This is called the external photoeffect. On the other hand, the activated electrons may never escape from the semiconductor but may be raised to a higher energy level such as the normally empty band. These electrons, together with the vacancy or "hole" in the normally filled band, will act as electron and hole carriers and will thus increase the conductivity of the semiconductor. This process is called the internal photoeffect.

The mechanism of the external photoeffect is illustrated in Figure 1. Here a light quantum, $hv$, is absorbed by an electron near the top of the filled band and receives enough energy to overcome the forces which tend to hold it in the solid ($\varphi e$) and to have some energy left after it escapes into the vacuum. The energy, $E$, is said to be zero for an electron at rest in the vacuum. The quantitative relationship between the frequency $v$ and the energy $E$ is given by

$$hv = E = \varphi e + (KE) \qquad (1)$$

where

$h$ = Planck's constant = $6.55 \times 10^{-34}$ joules $\times$ second
$v$ = Frequency of incident light in number per second
$E$ = Energy of quantum in joules
$\varphi$ = Voltage equivalent of energy necessary for electron to just barely escape
$e$ = Charge on electron = $1.6 \times 10^{-19}$ coulombs

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A compilation based upon the following three papers presented at section *B* of the Symposium on Electrical Properties of Semiconductors and the Transistor held during the AIEE Summer General Meeting in Swampscott, Mass., June 20–24, 1949: "General Features of Photoconductivity and Photoemission in Semiconductors," **Lloyd Smith,** Cornell University, Ithaca, N. Y., and session chairman; "External Photoelectric Effects in Semiconductors," **LeRoy Apker;** "Internal Photoeffects in Germanium," **J. N. Shive,** Bell Telephone Laboratories, Inc. The compilation was prepared by **J. A. Becker** (F '43), Bell Telephone Laboratories, Inc., Murray Hill, N. J.

* See *Electrical Engineering* for October 1949, pages 865–72.

If the frequency has the value $v_0$ such that $hv_0 = \varphi e$, then the electron can just barely escape. If $v$ is less than $v_0$ the electron cannot escape. If $v$ is greater than $v_0$ then the electron will have kinetic energy, ($KE$) in the vacuum equal to $hv - hv_0$. If the light quantum is absorbed by an electron below the top of the filled band it must absorb a quantum of energy greater than $hv_0$ before it can escape with zero kinetic energy. Hence by studying the velocity distributions of the electrons which escape into the vacuum, at various frequencies of incident light, the physicist can determine the position of the top of the filled band and some information on density of population of electrons in the filled band. For simplicity, in Figure 1, the empty band is not shown.

The mechanism of the internal photoeffect is illustrated in Figure 2, which shows two low-lying filled bands and a normally empty conduction band. These energy bands are separated by unallowed bands or gaps. These allowed bands are the analogues of the allowed energy states of the isolated individual atoms which compose the solid. When the solid is formed from isolated atoms, the orbits of one atom interact or overlap with the orbits of its neighbors. The closer the approach between atoms, and the greater the extent of this overlapping, the wider will be the band. The number of electrons in a band is approximately equal to the number of atoms in the solid. Since in an isolated atom, not all allowed energy states are filled, not all of the energy bands will be filled. Naturally the low-lying allowed bands will be filled and the higher lying bands will be empty. It is a principle of quantum mechanics that when a band is completely filled, the electrons in it cannot contribute to the conductivity. However, when an electron is removed from the filled band, the vacancy or hole can be filled by a neighboring electron which then creates a new hole. In this way the hole can move along in an electric field. It acts like an electron with a positive charge and thus can contribute to the conductivity.

When an electron is raised from the filled band into the

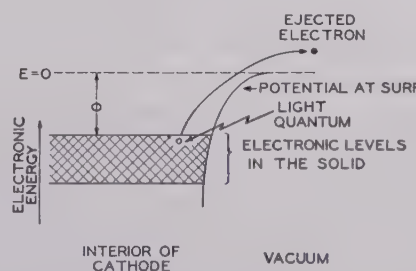


**Figure 1. Schematic of mechanism of external photoeffect**

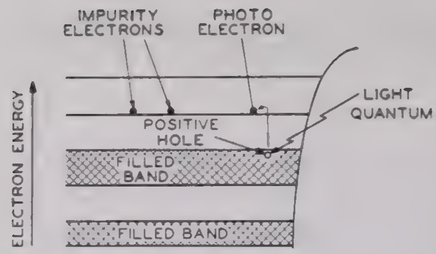


**Figure 2. Schematic of mechanism of internal photoeffect**

next higher empty band, as illustrated in Figure 2, both the electron and the hole contribute to the photocurrent. The quantum of energy required to do this is less than that required to produce external photoelectrons. Hence, photoconductivity can be produced by light of smaller frequency or longer wave lengths than that required to produce external photocurrents. For typical semiconductors, the gap between the top of the filled band and the bottom of the empty band corresponds to a few tenths of volts, say 0.5 volt. To bridge this gap, the wave length of the light must be shorter than 2.46 microns or $2.46 \times 10^{-4}$ centimeter. This relationship is given by equation 2 which is derived from equation 1.

$$\lambda V = 1.23 \text{ micron volts} \tag{2}$$

$\lambda$ = wave length in microns ($10^{-4}$ centimeters)
$V$ = energy of the electron expressed in equivalent volts

Thus for an unallowed gap of 0.5 volt, light of a wave length greater than 2.46 microns would produce no photoconductivity. This wave length is in the near infrared. Hence, from an experimental determination of the long wave limit for photoconductivity it is possible to deduce the height of the unallowed gap between the filled band and the conduction band.

In Figure 2 there are shown some electrons in the conduction band marked impurity electrons. These are electrons which are raised to the conduction band from donor impurities by thermal agitation. Hence, they produce conductivity in the dark. If the sample of semiconductor has a high concentration of impurities, this dark current may be so large that it will swamp the photocurrent. In such cases the photocurrent may still be studied by chopping the light, thus producing a small a-c ripple superimposed on a steady direct current, amplifying the alternating current and rectifying it.

Thus far, only interactions between a quantum of light and electrons in the filled band have been discussed. Actually there are electrons in the donor impurities and there are some electrons in the conduction band; these too might conceivably be activated by a quantum and thus produce photoeffects. Actually these photocurrents are usually very small compared with those originating in the filled band. In most cases the concentration of donors is small compared to the concentration of electrons in the filled band—perhaps one donor impurity for 1,000 electrons in the filled band. Even if the concentration of electrons in the conduction band were appreciable they would contribute only a small current to the external photoeffect. The reason for this is that these electrons are comparatively loosely bound to any particular atom and in order to react with a quantum of light both the energy and the momentum must be conserved. The momentum can be conserved only if a massive body such as an atom enters into the reaction. This can happen for the filled band but not for the conduction band.

## MAGNITUDE OF THE PHOTOCONDUCTING CURRENT

When an electron is put into the conduction band of a crystal and it moves a distance $x$ in the crystal its contribution to the current in a circuit of which the crystal is a part is just $ex/l$ provided $x$ is less than $l$ (the length of the crystal). If each electron remains on the average a time $\tau$ in the conduction band and the mobility is $\nu$ then the current due to $n$ electrons put into the conduction band per unit time at the same place in the crystal would be

$$i = \frac{ne\nu F\tau}{l} \tag{3}$$

where $F$ is the electric field in the crystal. In cases where the whole crystal is illuminated and part of the electrons go all the way through, the current can readily be calculated but aside from the number $n$ of electrons in the conduction band its magnitude will be determined by the combination $\nu F\tau$.

At the present time for most crystals these quantities are not known. Crystals differ widely in the magnitude of photocurrents and even for a given type of crystal, $i$ varies enormously with temperatures as in the case of BaO. The average life, $\tau$, has been measured for several crystals, it being of the order $10^{-6}$ second for AgCl and $10^{-9}$ in diamond. $\tau$ will depend on the probability of electron trapping in the crystal. Polarization effects influence $F$, and $\nu$, and in some cases $\tau$, can be sensitive functions of the temperature. Separate experiments show that $\tau$ may also change with the field strength $F$.

If the holes vacated by electrons thrown up into the conduction band also move, then they contribute to the photocurrent by an amount given by the foregoing formula wherein $\nu$ and $\tau$ may be different for the holes.

## SECONDARY PHOTOCONDUCTIVITY

In the foregoing discussion of the magnitude of the photocurrent, the current was proportional to the number of electrons raised to the conduction band per unit time which

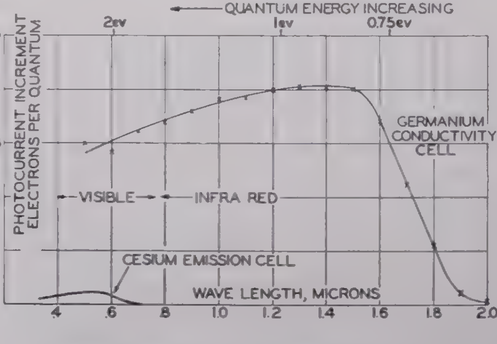


**Figure 3. Photoconductivity in germanium as a function of wave length of incident light**

in turn could not be greater than the number of incident quanta per second. However, there are solid materials which do not conduct appreciably in the dark but conduct well under illumination, so well in fact, that it would appear as though several thousand electrons were being put into the conduction band per quantum absorbed. Since this is impossible the large effect is thought to be a secondary effect. Many things such as the time required to reach maximum current, and so forth, make this interpretation plausible. Mott and Gurney have advanced the hypothesis that the primary photoeffect lowers the potential barrier at the metal-semiconductor interface. In the case of CdS, a notable case in point, Rose has advanced the idea that most of the CdS is a good semiconductor but conductivity in the dark is prevented by barriers in the body of the material such as $n$ to $p$ type boundaries and the like. On illumination the absorption of quanta serve to lower the barriers and the crystal conducts very much like a semiconductor, the light in effect just operates a valve. Current densities through needles of CdS can be of the order of amperes per square centimeter.

## PHOTOCONDUCTIVITY IN GERMANIUM

The spectral response of a photoconductivity cell using germanium as the semiconductor is shown in Figure 3. The abscissa is in wave length units, and the ordinate is in units indicating the amount of the response at the various wave lengths. Observe that germanium is photoconducting out to about 1.9 microns in the infrared. Some other semiconductors have responses which go to still longer wave lengths.

The cutoff wave length of 1.9 microns corresponds to a quantum energy just barely sufficient to activate an electron across the forbidden energy gap. The value of this activation energy, determined from the long wave threshold for germanium, is approximately 0.65 electron volt. This activation energy can be measured in other ways also; for example, by observing the change in conductivity with changing temperature at high temperatures, and values so obtained are in good agreement with the photoelectric value.

In Figure 3 also is shown for comparison purposes a spectral response curve for a photoemission cell. Its response is seen to be lower than that of the photoconductivity cell, and the wave length region in which its response occurs is much more limited. In addition, this wave length region is one in which the quantum emission from an incandescent filament light source is comparatively low. The reason why conductivity cells are not universally preferred, in view of these advantages, is that their response is linear with light flux only for limited ranges of light flux variation.

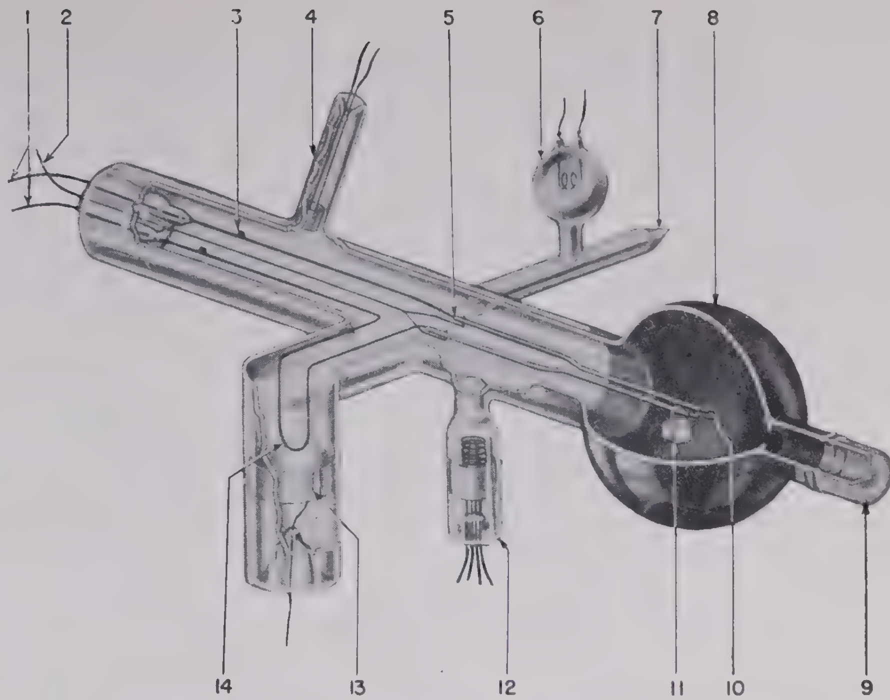


**Figure 4. Phototube for measuring the thermionic emission, photoelectric emission, and contact potential of barium oxide by the method of interchangeable emitters**

1. *Leads for center wire of shielded hairpin (shields start at 5 and center wire is exposed again at 10; shields eliminate stray fields due to uncontrolled contact potentials arising on hairpin)*
2. *Lead to contacts for hairpin shields (one contact may be seen just to the right of 5; the contacts spring away from shield to let bucket go by)*
3. *Bucket retainer for buckets not in use*
4. *Barium oxide evaporation source*
5. *End of hairpin shield with spring contact just to right*
6. *Getter bulb (tungsten or Ta-Th alloy)*
7. *Seal-off tip*
8. *Graphite collector for photoelectron retarding potential measurements*
9. *Quartz window for admitting ultraviolet*
10. *Exposed center wire of shielded hairpin*
11. *Typical bucket (8 to 14 of these were used in actual tubes)*
12. *Ionization gauge*
13. *Slit ring collector for thermionic emission from buckets (slit was to prevent induction heater from getting the ring hot instead of the bucket)*
14. *Hairpin on which buckets were hung during thermionic measurements*

## EXTERNAL PHOTOEFFECT

The study of photoelectric emission played an important role in the early devlopment of quantum theory shortly after 1900. Later, in the 1930's, it afforded one of the most direct demonstrations of the validity of quantum statistics as applied to the free electrons in metals. It is now entering another stage of development, and is becoming a useful tool for investigating the behavior of electrons at free surfaces of metalloids and semiconductors.

The fundamental method was developed by Millikan in 1915, and Condon later pointed out its value for studying semiconductors. Experimental results, however, have been obtained only in the last few years, chiefly by Apker and his associates at the General Electric Company. The technique involves two main steps. For reference purposes, one first determines the distribution in energy of the photoelectrons ejected from a simple metal by photons having a

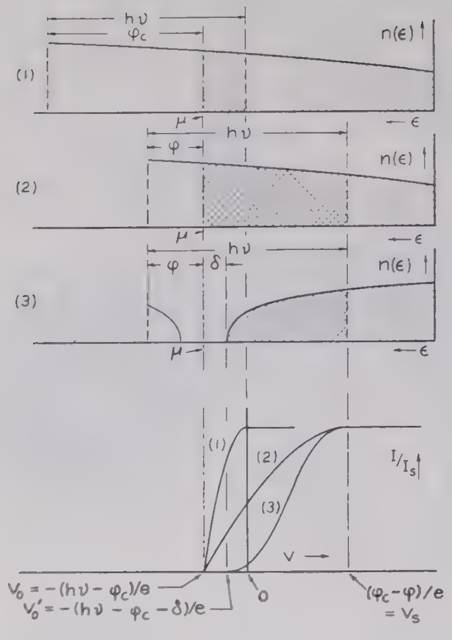


**Figure 5. Schematic diagram showing the density of electron energy states n(ε) as a function of energy ε for the following**

1. *An ideal metal with a comparatively high work function $\varphi_c$*
2. *A metal with a lower work function $\varphi$*
3. *An ideal intrinsic semiconductor also with a work function $\varphi$*

*Note that ε increases from right to left. Occupied states from which external photoelectrons can be excited by radiation of frequency v are cross-hatched; other occupied states are shaded. Below the energy diagrams are theoretical current–voltage characteristics derived for a spherical phototube. The number next to each curve designates the emitter material; the collector is assumed to be made of metal 1. The saturation line, shown as $I/I_s=1.0$, has a small but measurable slope due to the Schottky effect, which is neglected in this figure*

single energy. This is done by setting up known electric fields to retard the electrons in a phototube having a simple spherical geometry. Provision is made to replace the metal with the semiconductor to be investigated, the two being held in thermal and electrical equilibrium. If this is done without changing other conditions, rather direct information may be obtained about the following characteristics of the semiconductor:

1. The work function, that is, the energy difference between the Fermi level and the top of the surface potential barrier that tends to keep electrons from leaving the material.
2. The width of that part of the forbidden band of energy states that lies between the Fermi level and the densely occupied band below it.
3. Qualitatively, the form of the upper part of this occupied band.
4. Semiquantitatively, the number of energy levels associated with surface states and with impurities near the surface.

Independently, the results may be checked for reliability by varying the energy of the incident photons. Some idea of the uniformity of the surface may be obtained by applying relatively large accelerating fields to investigate the Schottky effect.

In forming a more complete picture of an electronic energy structure, photoelectric data are valuable for comparison with the following information obtained by other well-known methods of investigation: optical absorption spectra, thermionic emission, Hall effect, photovoltaic effects, and electrical conductivity.

Figure 4 shows the form of tube used in experiments on the external photoeffect. The description of the various parts of the tube is given in the caption. Light of essentially a single frequency, $v$, is made to fall on the bucket 11 or cathode. This bucket may consist of any metal or any semiconductor. The quantum of energy, $hv$, gives up its energy to a variety of electrons in the material of the cathode. Some of these electrons will then have sufficient energy to overcome the surface forces of the cathode, and still have some energy left over. Let $E$ represent this energy. The voltage equivalent of $E$ will range from 0 to a few volts depending on the value of $hv$ and the work function of the cathode, $\varphi$. The range of values of $E$ are deduced from experimental values of the current reaching the collector as a function of the voltage applied to the collector. If this voltage is above a certain value, $V_s$, all the electrons escaping from the cathode are collected and the current is saturated. Hence the subscript $s$. For an applied voltage $V_s$, the field between the cathode and collector is zero. For any voltage less than $V_s$, the field is a retarding one and will prevent those electrons with small values of $E$ from reaching the collector and being measured. Hence as $V$ is made more negative, the current to the collector decreases from $I_s$ to zero. The potential at which $I=0$ is called the stopping potential and designated by $V_0$. This is the voltage which can stop the fastest electron or the one having a maximum value of $E$ or $E_m$. Millikan and others showed that all metal cathodes had the same value of $V_0$. Different metal cathodes have different values of $V_s$. On the other hand, different semiconductors have neither the same value of $V_0$ nor the same value of $V_s$; they also have a different shape of curve for $I/I_s$ versus $V$. The reason a spherical collector is used is that it will stop an electron of a particular energy $E$ no matter what direction it has when it leaves the cathode. The shape of experimental current voltage curves can thus be used to deduce values of $E$, or more explicitly the distribution in energy of the electrons emitted from the cathode. From this distribution, it is possible to deduce the energy the electrons had in the cathode before they reacted with the quantum and the number of electrons having energies between $\epsilon$ and $\epsilon+d\epsilon$. This is called the density of electron energy states and is represented by $n(\epsilon)$.

Figure 5, in its upper part, shows the form of $n(\epsilon)$ versus $\epsilon$ for two metals and one semiconductor. This form is based partly on quantum mechanical theory and on deductions based on experiments. In the lower part of the figure are shown three curves of $I/I_s$ versus $V$ which should be experimentally observed in three experiments for the three cathodes whose distribution curves are shown in the upper part.

In Figure 5 there appear three quantities, $\mu$, $\varphi$, and $\delta$ which need further elucidation. The quantity $\mu$ is the energy of the Fermi level. This quantity plays an important part in all theories of metals and semiconductors. It is that energy level at which the probability of finding an electron is one-half. For energy levels much greater than $\mu$, the probability of being occupied by an electron is very

small; for energy levels much less than $\mu$, the probability of being occupied by an electron is very great. When different metals or semiconductors are in electrical contact and in equilibrium, the energy levels of these components of the system will readjust themselves until the Fermi level is the same throughout the system. In metals, the Fermi level is always inside of an allowed energy band. In semiconductors, the Fermi level is always inside of an unallowed energy band or gap; its exact location in this gap is determined by the concentration of donors or of acceptors and by the temperature; for a pure semiconductor, $\mu$ is in the middle of the gap for all temperatures.

The Fermi level permits one to give a precise definition of the work function, $\varphi$, namely the work required to take an electron having an energy equal to the Fermi level $\mu$ and remove it from the solid against the forces which tend to keep it in the solid. When a collector with work function $\varphi_c$ is in contact with a cathode of work function $\varphi$, there exists in the space between them a contact potential difference equal to $(\varphi_c-\varphi)/e$ volts.

The quantity, $\delta$, in Figure 5 is a measure of the energy difference between the Fermi level and the top of the filled band in a semiconductor.

From the foregoing definitions, it follows that

$$E=\epsilon+h\nu-(\mu+\varphi) \tag{4}$$

and also that

$$E=\varphi_c-\varphi-Ve \tag{5}$$

Hence

$$\epsilon+h\nu=\mu+\varphi_c-Ve \tag{6}$$

or

$$Ve=\varphi_c-h\nu+\mu-\epsilon=-(h\nu-\varphi_c+\epsilon-\mu)$$

In the foregoing discussion, the zero of energy for $\epsilon$ and $\mu$ was taken at any arbitrary distance below $\mu$. If we choose to measure energies from the Fermi level, then $\mu=0$ and and values of $\epsilon$ in the occupied levels will be negative quantities. It is also clear that for a metal, the fastest electron will originate at the Fermi level for which $\mu=0$ and $\epsilon=0$. The applied voltage $V$ which will stop such an electron from reaching the collector, which we call $V_0$, will be given by

$$V_0e=-(h\nu-\varphi_c) \tag{7}$$

Since this equation is independent of $\varphi$ it follows that all metal cathodes should have the same stopping potential $V_0$.

For a semiconductor, the fastest electron from the filled band will originate in a level $\delta$ below $\mu$ for which $\epsilon=-\delta$. Hence it follows that the stopping potential for a semiconductor, which we call $V_0'$ will be

$$V_0'e=-(h\nu-\varphi_c-\delta)=V_0e+\delta \tag{8}$$

From the definition of contact potential given in the foregoing, it follows that $V_s$, the applied potential at which the photocurrent saturates, is given by

$$V_se=\varphi_c-\varphi \tag{9}$$

In an experiment with different metal cathodes, $h\nu$ will be known and $V_0$ and $V_s$ are given by the experiment. Hence $\varphi_c$ can be calculated from equation 7 and $\varphi$ from equation 9. If semiconductors are then used as cathodes with the same collector, $\varphi$ for the semiconductor can be calculated from equation 9 and $\delta$ from equation 8. In an actual experiment $\varphi_c$ may be nonuniform because different regions of the collector will have various values of its work function. This will result in a rounding off of the $I/I_s$ curve near $V_s$ and only an average value of $\varphi_c$ can be calculated. Similarly different regions of the semiconductor may have nonuniform values of $\delta$ because the concentration of donor or acceptor impurities may vary from one region to the next. This will make the approach of the curve to zero current near $V_0'$ more gradual than that shown in Figure 5.

Figures 6 and 7 are experimental curves of $I/I_{10}$ versus $V$ that illustrate the utility of this technique. The dotted curve in Figure 6 is for a typical metal for which $\varphi=4.66$ while the solid curve is for the metalloid arsenic for which $\varphi=4.66$ volts. In this experiment, the work function of the collector, $\varphi_c$, was also 4.66 volts, so that $V_s=0$. $h\nu$ was 6.71 volts. Hence from equation 7 $V_0=6.71-4.66=2.05$ volts. This value is indicated by the solid arrow. The small tail near $V_0$ is due to the fact that the experiment is done at 300 degrees Kelvin rather than 0 degrees Kelvin.

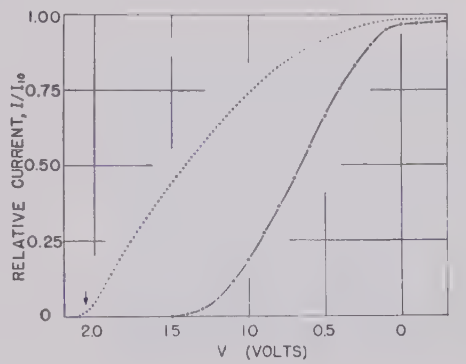


**Figure 6. Current-voltage characteristics for amorphous As and for a metallic emitter with the same work function, 4.66 ev**

*The arrow marks $V_0$, the "stopping potential for 0 degrees Kelvin." The saturation points are at $V=0$. Currents are normalized at $V=+10$ volts. For As, $I/I_{10}=1.10$ at $V=+400$ volts. To avoid confusion, only a few of the experimental points are given. $T=300$ degrees Kelvin; $h\nu=6.71$ ev*

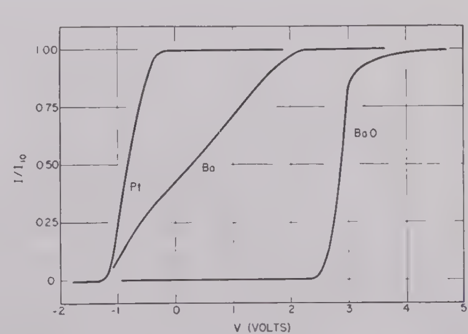


**Figure 7. Photoelectric current-voltage curves for Pt, Ba and BaO**

*Showing that occupied band in BaO is 3.7 volts below the Fermi level at 300 degrees Kelvin*
*$h\nu=5.80$ volts; $\varphi_c=4.65$ volts; $V_s$ for BaO $=3.1$ volts; $V_0=-1.2$ volts; $V_0^1$ for BaO $=2.5$ volts*

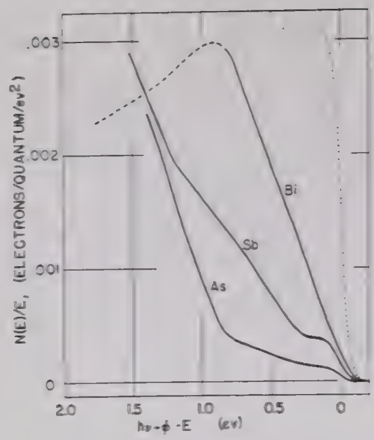


**Figure 8. Density of electrons in occupied states near and below the Fermi level at 300 degrees Kelvin for As, Sb, Bi, and a metal (dotted curve)**

*The Fermi level is at 0 volt for all curves*

At 300 degrees Kelvin an appreciable number of electrons are raised to energies slightly higher than $\mu$. Hence they require a slightly higher value of stopping potential than $V_0$. Note that the stopping potential for As is $2.05-1.5$ or 0.55 volt less than that for a metal. Hence it can be concluded that the top of the filled band is 0.55 volt below the Fermi level. From the fact that the solid curve rises more gradually than does the metal curve, it can be concluded that the density of states in the filled band of As near the Fermi level is not as great as that in a metal and increases for values of $\epsilon$ below the Fermi level.

Figure 7 shows experimental curves for Pt, Ba, and BaO. For this experiment $h\nu$ was 5.80 volts; $T=300$ degrees Kelvin: $\varphi_c=4.65$ volts. Since $V_s$ for BaO$=3.1$ volts, $\varphi$ for BaO is approximately $4.65-3.1=1.5$ volts. For a metal having this same work function the stopping potential $V_0$ should be $5.80-1.5=4.30$ volts more negative than $V_s$ or at $3.1-4.3=-1.2$ volts. This is actually the value found for Pt and Ba. However for BaO the actual stopping potential $V_0'$ is found to be 2.5 volts. Hence $\delta=2.5+1.2=3.7$ volts, so that the top of the filled band is 3.7 volts below the Fermi level at 300 degrees Kelvin. This makes it highly probable that the Fermi level is near the top of the unallowed gap since the total gap cannot be much greater than 3.7 volts. Hence BaO should be an *n*-type semiconductor which agrees with deductions for thermionic and thermoelectric data.

Figure 8 is a plot of $N(E)/E$ versus $h\nu-\varphi-E$ for As, Sb, and Bi. The function $N(E)$ is obtained from the slopes of experimental $I/I_s$ curves. The quantity $N(E)/E$ is proportional to the total number of electrons released from the cathode per quantum of light energy. A more involved theory states that this is proportional to the density of electron states in the filled band of the semiconductor multiplied by the probability that the quantum $h\nu$ will react with that energy state. The quantity $h\nu-\varphi-E$ is equal to $\mu-\epsilon$ and hence is the energy expressed in equivalent volts below the Fermi level. In Figure 8 the dotted curve is for a metal and shows the density of electrons in a metal. Note that it is horizontal or constant for values greater than a few tenths of volts below the Fermi level. At the Fermi level (0 in Figure 8) its value is one-half of the maximum value; and above the Fermi level it drops to zero in a few tenths of volts. At 0 degrees Kelvin this curve would drop abruptly to zero from its maximum value for $x=0$. Note that the density of states for Bi, Sb, and As below the Fermi level is considerably less than it is for a metal and that it decreases in the order Bi, Sb, As. This agrees with the fact that Bi acts more like a metal than does As in many physical and chemical properties. Note also that there is considerable structure in the density of electron states as indicated by the plateau for the Sb curve at about 0.2 volt. This suggests that the allowed energy bands in Sb overlap each other. Such a conclusion is in accord with quantum mechanical theory for some metals and metalloids.

The reader who is interested in pursuing this subject farther is referred to the list of references to books and original articles.

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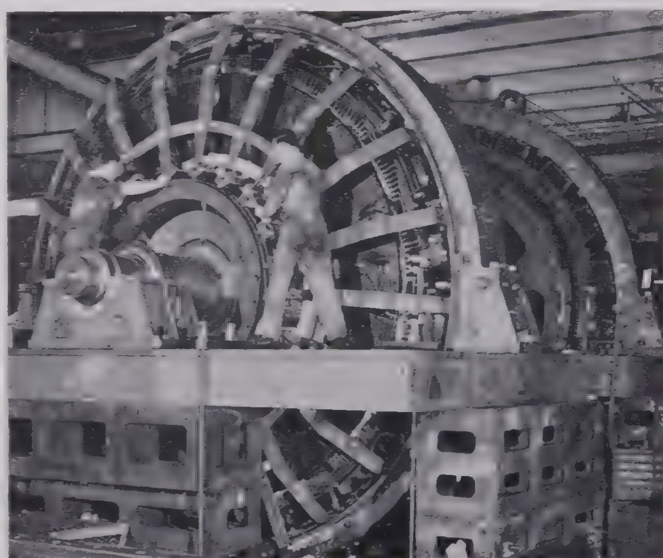
# Hot Strip Steel Mill Motors



**Two 5,000-horsepower drive motors for Kaiser's new semi-continuous hot strip steel mill at Fontana, Calif., are being prepared for testing at the General Electric Company's Schenectady (N. Y.) works. Power to drive the strip mill will be supplied by one 3,500-horsepower and three 5,000-horsepower motors. Rectifiers alone will convert the alternating current supplied to the mill to the direct current required by the drive motors**

# Electrically Charged Dust in Rooms

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ELECTROSTATIC precipitators operated at high cleaning efficiency have been very effective in keeping room walls and furnishings clean. However, the operation of precipitators at relatively low cleaning efficiency may result in serious trouble because of the escape of dust carrying electric charges of one sign into the rooms.

In an electrostatic precipitator, the particles first are given an electric charge of one sign (usually positive). Then they are passed through a collector cell whose function it is to remove these charged particles from the air stream by precipitating them on its plates. If charged particles are allowed to escape, they set up a space charge in the room. The resulting voltage gradient causes charged dust to migrate toward the walls and other exposed surfaces.

The rate at which dust moves in the electrostatic field varies directly with the voltage gradient. The gradients produced by space charge are higher near surfaces projecting into the room, and conversely are lower on partially shielded surfaces. For this reason, surfaces projecting into the room, such as light fixtures, are soiled more rapidly by space charge precipitation than receding, or partially shielded surfaces.

These effects were demonstrated using a low-efficiency precipitator, in which leakage of charged dust through a passage by-passing the collector cell, resulted in a cleaning efficiency of only 50 per cent. Potentials, built up in the center of the room by space charge and measured by means of an electrostatic voltmeter, were found to be high when the air was dirty and essentially zero when the air was clean.

To show the effect of voltage gradient at a surface, two small metal cylinders, upon which strips of white paper were wrapped, were suspended in high-potential regions in the room, far enough apart to prevent any appreciable influence upon each other. One probe was suspended by a grounded wire, so that space charge would produce at its surface a voltage gradient much higher than that at the room walls. The other probe was insulated from ground by using a fine waxed silk-thread suspension to allow the probe to attain essentially the potential of the space, thus keeping the voltage gradient at its surface low. The insulated probe remained clean while the grounded probe blackened rapidly, showing the effect of voltage gradient.

Figure 1 shows the pattern of dirt deposition on the room wall by space charge. Using Poisson's equation, it can be shown that for geometrically similar rooms the voltage gradient at the wall varies directly with the room size (linear dimension) and directly with the electric charge density in the room. The velocity with which the dust is driven toward the wall is proportional to the voltage gradient, and the rate of deposition on the wall is proportional to the product of this precipitation velocity and the dirt concentration in the air.

The charge per unit of dirt escaping the precipitator probably is constant when the efficiency is constant, but if the efficiency is decreased either by increasing the air velocity or by decreasing the plate voltage, the charge per particle probably increases.

Accordingly, the rate of discoloration caused by space charge varies as the first power of the room size (linear dimension) for geometrically similar rooms, as the second power of the dirt content of the air, and as a power of the precipitator inefficiency (one minus cleaning efficiency of the precipitator or $1-e$), which is probably higher than the square, perhaps more nearly the cube. Since space-charge discoloration varies so rapidly with the inefficiency $(1-e)$, it is very important to use an efficient precipitator properly installed and maintained.

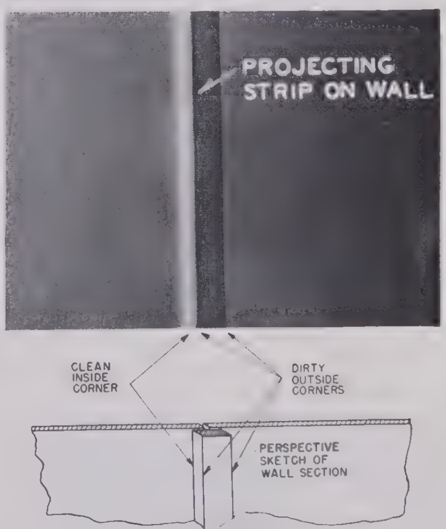


**Figure 1. Typical space - charge blackening at a projecting strip on a wall (note clean inside corners) and a perspective drawing of the wall construction are shown**

Under particularly severe conditions, a neutralizing scheme may be desirable. One method has been devised, in which a neutralizer, operated from the main power pack, takes a fraction of the air leaving the precipitator and charges the particles strongly negatively, so that the resultant negative and positive charges are balanced and well mixed. This system has been found to reduce space charge to about ten per cent of that produced without neutralization.

In ordinary locations and for rooms of moderate size, the general experience has been that a precipitator operated at high cleaning efficiency does not give space-charge difficulties. Special attention should be given to large rooms in especially dirty locations.

Digest of paper **49-74**, "Electrically Charged Dust in Rooms," recommended by the AIEE Electronics Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Trackless-Trolley Operation

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ALTHOUGH the trackless trolley may not be a cure-all for transit ills, it has proved to be a most satisfactory vehicle for mass passenger transportation. The United Electric Railways Company of Providence, R. I., starting with a fleet of five in 1931, now operates 330 trolley coaches. These 17 years have been a source of invaluable experience in every phase of operation, including vehicle storage, overhead construction, vehicle maintenance, and economic performance.

It has been found that, in spite of the rigors of New England winters, outdoor storage of trackless trolleys offers no serious operating difficulties and is most economical. A properly paved, well lighted area, with provisions for fire lanes and fire-fighting equipment, and one pair of overhead trolley wires for each of the two lanes of coaches can be provided for about $432 per vehicle, exclusive of land value.

Trackless trolley overhead construction being a vital part of the entire plant and being that particular part subject to scrutiny by the entire community, its appearance must receive serious consideration. Methods resulting in excellent appearance at moderate cost have been developed covering every phase of overhead construction from setting poles to installing special work at intersections. These methods include such things as concrete pole ground bracing, a unique preloading method of installing span wires, rollers for hanging and tensioning of trolley wire, and shop assembly of intersections.

Maintenance of trackless trolleys in Rhode Island is performed by the department responsible for motor-bus maintenance. The decision to assign trolley coaches to the bus department was debated at great length in 1931, but time has proved it to be an excellent one. The term "protective maintenance" truly describes the system used in this department. The inspection and maintenance of each part is scheduled on a vehicle mileage basis, and experience has permitted these functions to be grouped into four inspection intervals: namely, at 2,000 miles, 6,000 miles, 24,000 miles, and 240,000 miles. This system of maintenance has resulted in excellent performance at moderate cost. In 1947, the trackless-trolley fleet operated 5,476 miles per road call due to electrical failures, and 1,676 miles per road call due to all causes, and the direct cost of labor and material amounted to 2.81 cents per mile.

Having converted 30 lines from rail to trackless-trolley operation with a short interval of motor-bus operation on each line during the construction of overhead, it has been found that motor busses generate about five per cent additional revenue and trackless trolleys about ten per cent additional revenue.

Speeds have been increased from 5.3 to 23.7 per cent over corresponding rail operations with an average increase of 17.3 per cent. Earnings per vehicle mile in 1947 ranged from 48.14 to 78.33 cents with an average of 57.32 cents, while operating expenses ranged from a low of 42.63 to a high of 57.18 cents, averaging 45.73 cents.

The number of passengers carried in the maximum hour varies from a low of 285 to a high of 1,573 with a system figure of 699 per line. The service required in the p. m. peak ranges from a 2-minute headway to a 10-minute headway with an average of 4.49 minutes. The 30 trackless-trolley lines range in length from 1.78 miles to 5.84 miles, averaging 3.09 miles, and earn $53,541 per route mile per year.

In considering a line for conversion, it is important to make a thorough study in order to determine correctly the proper vehicle to be used. It is not sufficient to use so-called yardsticks such as passengers carried in the maximum hour, revenue per route mile, and revenue per vehicle mile, although these yardsticks are of value in preliminary considerations.

The future of trackless trolleys in the transit industry is assured by their performance in the past. Trolley coaches have increased from 163 to more than 6,000 since 1931, and this trend is continuing. This growth is convincing proof that the trackless trolley has attained an important place in mass passenger transportation.

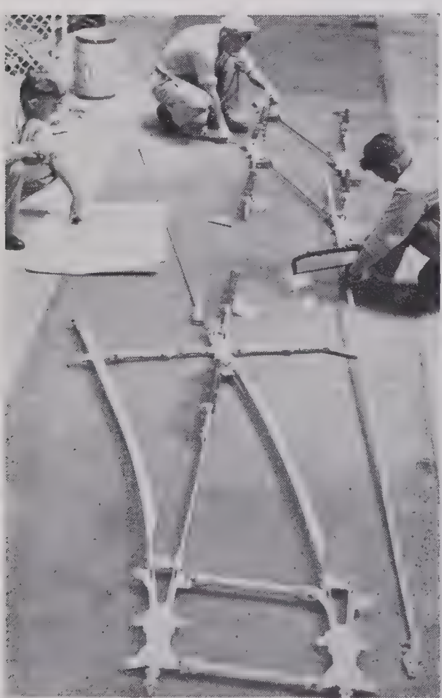

**Figure 1. Shop assembly of trackless-trolley intersection**

Digest of paper **49-104**, "Trackless-Trolley Operations in Rhode Island," recommended by the AIEE Land Transportation Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Of What Value Is History?

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THUCYDIDES, the celebrated Greek historian of the eventful epoch of the Peloponesian War (fifth century B.C.) believed that before his time nothing of importance worthy of relation had happened in the world. He was overwhelmed with his present and simply was not interested in the past.[1]

Such is approximately the attitude of the average modern engineer, also, of many a modern scientist, toward the past history of science and engineering. "Why should I worry about the past, when I can hardly keep up with the modern developments in my own line?" he says. The allergy to history is effectively inoculated in the engineer at schools, and it is further intensified by the usual surrounding of his bread-and-butter work during the rest of his life. His leisure time he spends in a variety of ways to rest his mind. But certainly he never would reach for anything historical. Being a history shunner he is in no position to realize that reading stories from the past history of science or of his own art might prove to be as interesting to him as a first class adventure story. Indeed, the whole progress of science and technology is full of the dramatic element and of the human touch. The reader of history would learn that science and related arts, as they are known to him now, have not reached the present heights on a smoothly paved way, with general acclamation of every new achievement. Very often, progress of science was hampered by a genuine struggle against all kinds of odds, such as psychological or ideological inertia to accept novel ideas about familiar phenomena, or, sometimes, simply against human pride, jealousy, and the established uncompromising scientific opinion. A good illustration of this is the story of the discovery of the law of conservation of energy.

**Of what value can a study of the history of his art be to the engineer? The wise man in any field can profit by examples from the past. For the scientist especially, the history books can teach much of the trials and errors of creative thinking, and indeed may point the way toward new paths to as yet unexplored realms of knowledge.**

It is well-known to the engineer that the law of conservation of energy is one of the basic laws of classical physics, especially important from the engineering viewpoint in thermodynamics. However, this law was not known to Newton or Galileo; neither was Lavoisier, the discoverer of the other basic law of modern science, that of conservation of matter, aware of it; nor was it used by Sadi Carnot, the founder of thermodynamics, in devising his famous thermal cycle. It is also known to the engineer from the textbooks that the mechanical equivalent of heat, the most important natural constant in thermodynamics and intimately connected with the law of conservation of energy, was measured by Joule. Therefore, Joule often is called the discoverer of this law.

History of science would tell the reader that, in spite of its simplicity—almost its obviousness (to us)—the law of conservation of energy is younger by half a century than its sister law of conservation of matter (1842 versus 1777); that Lavoisier (1743–1794) himself and all his contemporaries viewed heat as superfine fluid and called it "caloric"; that some of the scientists even tried to determine its weight; that the first who demonstrated by his famous friction experiments (1797) that heat actually was a kind of energy was Benjamin Thomson (1753–1814) of Boston, better known to science as Count Rumford.[2]* Finally, the reader may learn that the law of conservation of energy caused many serious troubles to its original discover.

## THE EXAMPLE OF MAYER

The basic idea of conservation of energy or of "force"—as it was called at that time—though sensed vaguely by some scientists, such as Sadi Carnot (1796–1832), looked absurd to many others. Thus, the first paper which briefly outlined this entirely new philosophical idea was pigeonholed by a leading German scientific magazine, Poggendorf's *Annalen der Physik*, in 1841, and never saw the light. The author of the paper, a modest practicing physician, Dr. J. Robert Mayer (1814–1878) of Heilbronn, Germany, finally succeeded in publishing a similar paper[3] in *Liebig's Annalen*, in 1842. However, instead of receiving honors, he was for years so ridiculed and morally persecuted by some professional scientists in lectures and daily press, that he first attempted suicide and finally ended his life in a lunatic asylum with a mania of persecution. And this happened in spite of the fact that after his first paper he wrote several others[4] in which the principle of conservation of energy was disclosed so completely that practically nothing basic had to be added by other scientists. All these papers Mayer had to publish himself, since no scientific magazine would accept them. In addition, Mayer's fault was that not being professional he stole the show from the others and refused to abrogate his claim for priority of the discovery in favor of recognized authorities in science.

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* It is interesting that a similar idea was thoroughly developed by Michael Lomonósov a Russian scientist, in his treatise, "On Causes of Heat and Cold," written in 1747. The author views heat as energy of vibrating molecules (called by him, "corpuscles"). Born in a poor peasant family, 1711, M. Lomonósov became in 1745 a member of the Academy of Science, St. Petersbourg, and professor in chemistry. Many remarkable writings of this genius on various scientific topics remained obviously unknown to the scientists of western Europe, probably because of the barriers of language.

About the same time, that is, during the 1840's, James Prescott Joule (1818–1889), also a self-made scientist, preeminently a remarkable experimenter, was making very successful measurements in his private laboratory in Manchester, England, on heat produced by electric current; then, on heat resulting from conversion of mechanical work.[5] Also, in Germany, Hermann Helmholtz (1821–1894), one of the greatest physicists of that time, presented in 1847 a brilliant mathematical paper on the very same subject, conservation of "force."[6]*

However, by that time Robert Mayer not only had completely formulated the new law, but also had calculated the mechanical equivalent of heat from then available data on specific heat of gases at constant pressure and at constant volume, published by Gay-Lussac, the French scientist.

It is rather astonishing that Robert Mayer arrived at his epoch-making idea through very simple observations, such as the varying alertness of the crew members on a voyage from Holland around Africa to Java, as the ship was traversing different climatic zones. Incidently, he also learned from the skipper of the boat that after big storms sea water becomes warmer than usual. However, he was most impressed by the peculiarly bright red hue of human venous blood in the tropical climate. Dr. Mayer was the ship's doctor on this trip and sometimes, in accordance with the medical practice of that time, had to bleed the sick sailors.[7] In his own words, the latter fact—long known to the physicians living in tropical countries—struck him like a lightning bolt, and an idea dawned on him that there was some connection between chemical reactions, mechanical work, and heat developed in the human body. Such a flash of of intuition reminds one of the story of Newton's law of universal gravity suggested to him by a falling apple.

The undisputable scientific authority of Helmholtz, who disliked Mayer's claim that he was the originator of the law of conservation of energy in competition with him (Helmholtz) was so great, that for a long time no one in Germany's scientific world ever dared to mention Mayer's name. Thus, Eugene Dühring, a privatdozent (assistant professor) in physics was expelled from the University of Berlin in 1872, because he openly recognized Robert Mayer's outstanding merits.[8] This he did in a paper, "Critical History of the Principles of Mechanics." In justice to Helmholtz it should be acknowledged that, although reluctantly, he finally conceded Mayer's priority.[9]

In England, from the very beginning, credit for the same law generally was given to Joule who was Lord Kelvin's friend and protégé. However, in 1862, in a public lecture before a large audience, John Tyndall, Faraday's successor in the capacity of the Director of the Royal Institution, openly recognized the outstanding merits of Mayer as the original author of the law of conservation of energy. He said:

> The writings of Mayer form an epoch in the history of this subject ... When we consider the circumstances of Mayer's life and the period at which he wrote, we cannot fail to be struck with astonishment at what he accomplished. Here was a man of genius working in seclusion, animated solely by a love of his subject, and arriving at the most important results in advance of those whose lives were entirely devoted to natural philosophy.

Many prominent British scientists took offense at these remarks by Tyndall, but his firm public reply to Joule's open accusation of lack of fairness[10] silenced all objections.[11] Yet, even now many British and American authors of textbooks on physics, while discussing the law of conservation of energy, do not even mention Robert Mayer's name. On one occasion, Lord Kelvin openly admitted that he would rather give credit for the law to Joule in preference to Robert Mayer because Joule was his fellow countryman.[12]

## OTHER EXAMPLES

In the history of science, Robert Mayer's story does not stand as an isolated case. In fact, practically every really great advancement in "natural philosophy" was invariably accompanied by a reluctance to accept it. The same can be said about many great engineering inventions. Perhaps one may view such behavior as a generalized Newton's third law of universal reaction, extended over the domain of the human mind. In earlier days, reaction took often the form of physical persecution, as in the cases of Giordano Bruno and Galileo. In more recent centuries, when science acquired general recognition, reaction would manifest itself simply in the inability to understand the new idea and silently ignoring it, or even openly opposing it. Numerous examples can illustrate this. Thus, the reading of William Harvey's (1578–1657) "Anatomical Exercise on the Motion of the Heart and Blood in Animals," which described for the first time the mechanism of blood circulation, was prohibited by the Paris faculty because it deviated from Hippocrates and Galen, the ancient authorities on medicine.[13] Faraday's revolutionary concept of electromagnetic phenomena was silently ignored by leading mathematical physicists of his time, such as Gauss, Weber, and others, until Maxwell seized upon Faraday's ideas and translated them into the language of mathematical symbols. Maxwell's theory itself was under suspicion for a quarter of a century. J. A. R. Newlands was ridiculed by his fellow British chemists for bringing to their attention, in 1866, periodicity in properties of chemical elements if arranged in order of their atomic weights (he called it the "law of octaves"). Jokingly, he was advised to arrange chemical elements in alphabetical order and to see whether he could discover some other useful law.[14] Yet, a similar idea more fully developed by the Russian professor Dmitri Mendeleyev and announced two years later in his "Principles of Chemistry" received universal recognition and became a cornerstone of modern physics and chemistry.

A somewhat similar incident occurred in the domain of radio. Sir Oliver Lodge in his "Talks about Radio"[15] relates how in 1879 George Stokes, an outstanding British physicist, being invited to witness Professor David Hughes' experiments on "wireless" transmission through the air, turned them down with a verdict that the observed phenomenon could be explained either by leakage or by some other known fact. Lodge commented on this case that "there is the danger of too great knowledge; it looks askance at anything lying beyond or beneath its extensive scope." If Hughes' experiments were heeded, Maxwell's theory perhaps would have been verified and accepted earlier.

* Helmholtz' paper, "On Conservation of Force," also was rejected by the *Poggendorff Annalen*, but it was published in abstract by another, newly founded periodical on which Helmholtz himself was an editorial reviewer. In a review he mentioned Mayer's work, but did not give any credit for it.

The few given case histories suffice to show that history of science, pure and applied, is full of human interest. But there is more to it. To an observant reader a closer acquaintance with history may bring realization that not only technical but also ideological obstacles, great and small, may be encountered by the man who has chosen to explore an untrodden path. The past examples of those who won their battles should inspire him with courage, hope, and persistence. Moreover, some case histories would forewarn the scientist or an engineer against his own intolerance and render him more prudent in pronouncing a hasty verdict about some "crazy ideas" of his fellow-in-art. History teaches definitely that an unorthodox idea today may become a law tomorrow. Numerous examples, even from modern engineering, can be given to illustrate this. Science also, right now, confronts with unsympathetic suspicion a new class of phenomena scientifically investigated and described by Dr. J. B. Rhine of Duke University;[16] they are known under a variety of names, such as extrasensory perception, telepathy, psychic phenomena, feats of subconscious mind, however the name is of no importance.

### SCIENTIFIC PESSIMISM

Study of history of science also would show clearly to the reader that immutable theories may lose their immutability under the pressure of new facts, new ideas, or new scientific methods. One may find case histories in which the greatest scientific authorities were not infallible in that respect. Take, for example, the case of Marquis Pierre Simon de Laplace, the outstanding mathematician and astronomer of the beginning of the 19th century. In his famous book, "Éxposition du Système du Monde," published in 1824,[17] he took great care to outline the future possibilities for astronomy, that is, the feasible boundaries for human knowledge of celestial bodies, which ever could be reached. He held that the main factor in new discoveries would be solely improvements in optical instruments; making perfect astronomic lenses, mounting telescopes on top of high mountains, building observatories nearer to the equator, and so on. Thirty-five years later, spectral analysis was applied to astronomy by Kirchhoff and Bunsen.[18] The new method made possible studying of the chemical composition of our sun, planets, and far-off worlds. In addition, spectral analysis permitted, from the Doppler effect, the determination of velocities of the remotest stars with respect to our solar system. Laplace could not even dream of such possibilities. It is noteworthy that the presence of spectral lines in the sun's spectrum already was known in Laplace's time, since they were discovered by Joseph Frauenhofer in 1814 and carefully catalogued by him.[19] But years of time and proper inspiration were necessary to transfer this discovery from laboratories to observatories.*

In his failure to foresee the tremendous future possibilities, Laplace does not stand alone in the history of science. A similar attitude can be observed in retrospect also in the domain of physics. Indeed, in his inaugural lecture, 1871, on experimental physics in the newly founded Cavendish Laboratory, J. Clerk Maxwell deprecates the opinion of his contemporaries believing that "in a few years all the great physical constants will have been approximately estimated, and the only occupation then left to men of science will be to carry on these measurements to another place of decimals."[20] A similar scientific pessimism resurged after the spectacular discovery of electric waves by Hertz, in 1887. The general belief now prevailed among the scientists that human knowledge of Nature indeed had reached its ultimate limits as the most important fundamental facts and laws of physical science had been discovered. High-precision measurements of Nature's constants were all that was left to a devoted physicist.[21] This was, for example, almost literally expressed by the noted physicist, A. A. Michelson in his Commencement speech at the University of Chicago in 1894.[22] It is amazing that such prophesy should have been made on the very eve of the discovery of X rays, radioactivity, the electron and other subatomic particles, and shortly before the advent of the quantum and relativity theories. All these and many subsequent developments have, since, completely changed our concept of many phenomena of the material world.

Generally, a retrospective view of science and engineering reveals to a history reader a fascinating picture of various modes of creative thinking, of its dangerous turns and of a variety of new paths which at any time may lead into new, as yet unexplored domains of knowledge. Perhaps it would disclose also that the greatest discoveries and inventions are unpredictable, just as are unpredictable the most important events in the economic, social, and political life of nations.

While digging into history's "waste basket," an observant reader may come across a wonderful suggestion for his own work, since many ideas of old could not be fully developed either because of the insufficient appreciation on the part of the contemporaries, or because of the lack of adequate technical means. For example, a quite modern development of "electrets" (the electric simile of magnets) is rooted in Faraday's idea described in 1838.[23] Another example is the wave guides playing such an important role in radio, radar, and television of the last ten years; they were conceived and discussed by Lord Rayleigh in 1897.[24] Again, the phenomenon of electron emission from incandescent bodies, first misunderstood and completely neglected,[25] 25 years later became the cornerstone of radio, television, and of everything which gave our time the name, "Electronic Age." Many similar examples could be cited.

### THE VALUE OF HISTORY

Studying history of science and related arts can help the engineer to see more clearly as to what place in the over-all picture of the general progress his own bread-and-butter work occupies, and what relation it has to other branches of knowledge. In this way, he will be in a better position to realize how he can help others in their work by his own knowledge and experience, also, how he can be helped by others. After all, there must be a difference between a well-educated engineer and a well-trained technician. According to Sir Richard Livingston's definition, "A technician is a man who knows and understands everything about his job except its ultimate purpose and its place in

* In a letter to Kirchhoff, William Thomson (Lord Kelvin) mentioned that the idea of application of spectral analysis to astronomy was suggested to him in a conversation by O. Stokes, in about 1850; and that since, he (Thomson) used to mention this possibility to his students in lectures. In a special article,[26] Kirchhoff defended his priority by pointing out that Stokes' idea never had been either published or applied practically.

the order of the Universe."[26] A complete understanding of all these factors must be among the assets of an educated engineer. Again, it seems only natural that any one should be, though mildly, interested in the past of one's own art, as it is natural to be interested in the past of one's own country, of the society to which one belongs, or of the institution for which one is working. An engineer or a scientist who has no interest whatsoever in the past of his art resembles, to a certain degree, a man afflicted with amnesia. Yesterday does not exist for him, and yet, he needs yesterday's experience for his future work, lest he do the same work over and over again.

Study of history usually arouses interest toward general progress of culture and civilization. This would make a specialist more broadminded and give him a more cultural outlook on modern developments. Lack of culture amidst the great achievements of civilization in our time resulted in a lopsided understanding of mankind's problems, and is perhaps the cause of the present world's troubles. The specialist can contribute intelligently to the general progress; he also should realize that by far not every invention contributes to humanity's happiness, although it may contribute to its comfort, often called "standard of living."

Unbiased history of science and engineering should show that many great discoveries and inventions have been made in more than one country simultaneously, or—if at different times—quite often without knowledge of similar work of others. Clear realization of this fact may contribute much to a mutual respect among nations, instead of contempt of others and mutual accusation of stealing important ideas. In fact, science should and may become a powerful tool in promoting universal peace instead of universal destruction.

It is hoped that the foregoing analysis of the benefits that may be drawn from acquaintance with the history of science and engineering sufficiently demonstrates that books and essays on historical subjects may be good reading even to a specialist entirely devoted to his cause. He should not be afraid to lose time on it; often, he may be benefited in a variety of ways without even realizing it. The great Maxwell himself, whose life was short and achievements very great, said on one occasion: "Every student of science should be an antiquary in his subject."[27]

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# Tracers Aid Telephone Research

**Radioactive isotopes made at Oak Ridge are being used by Bell Laboratories for research purposes. Above, a Bell scientist, aided by a mirror and working behind a shield of lead bricks, dilutes radioactive strontium chloride for experimental use**

# D-C Series Motor Speed–Torque Curves

G. W. HEUMANN
MEMBER AIEE

FOR many years control-circuit designers have used a method of calculating d-c series motor speed–torque curves which was described by A. A. Merrill in the *General Electric Review*, October 1933. Speed and torque are calculated with the following formulas

$$S=\frac{E}{K} \qquad T=KI_A$$

where

$S$=speed in per unit of rated speed
$T$=torque in per unit of rated torque
$E$=electromotive force in per unit of generated motor electromotive force at rated torque and rated speed
$I_A$=armature current in per unit of rated full-load current
$K$=a factor, expressed in per unit, which is a function of field current and armature current.

$K$ is derived from motor test data. To calculate performance of a motor driving a load, $K$ can be assumed to be a function of field current only. To calculate performance of a motor being driven by a load, as in the case of a crane hoist lowering a load, the effect of armature current on $K$ must be considered.

The foregoing formulas are rigorously correct only if $T$ is taken as the internal developed torque, whereas $K$ only can be determined experimentally from external shaft torque. Examination of measured motor loss data shows that the error introduced by calculating external shaft torque by the given formula is less than 0.02 per unit.

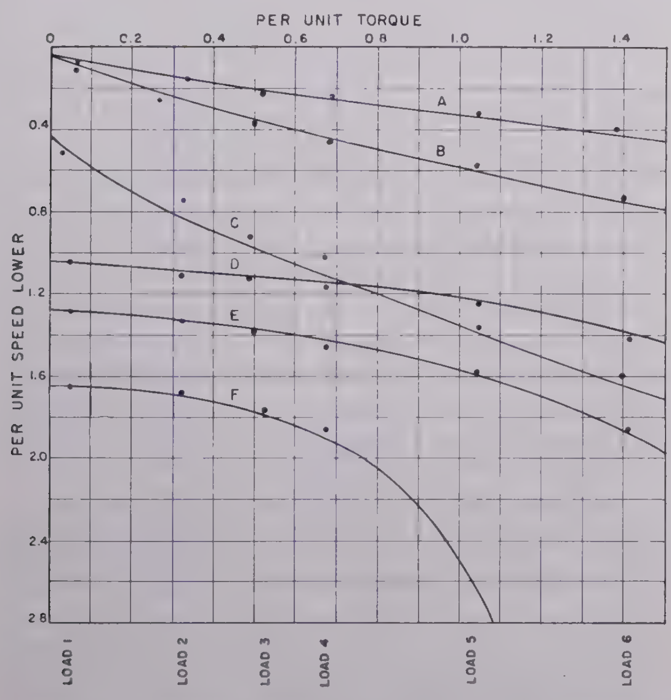


**Figure 1. Calculated speed-torque curves and test readings**

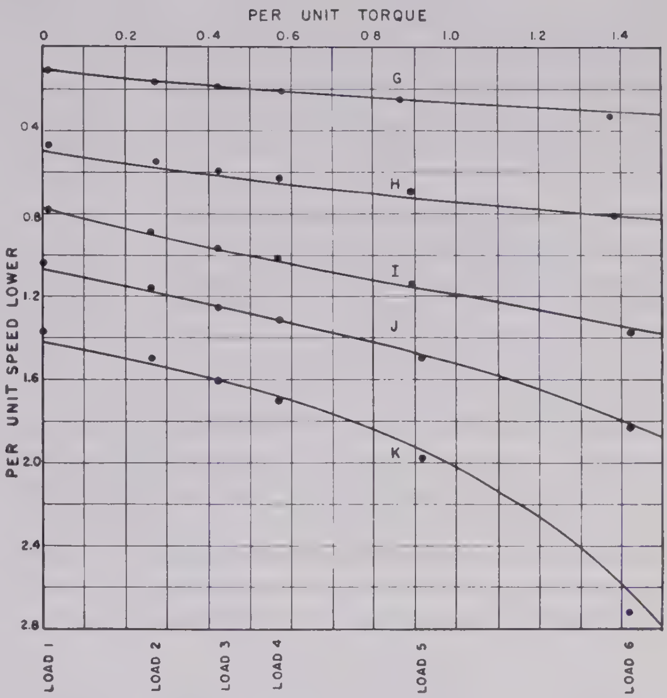


**Figure 2. Calculated speed-torque curves and test readings**

Speed–torque curves of a 50-horsepower series motor were measured on an experimental hoist, reading torque with an electromagnetic torque meter and speed with a d-c tachometer generator. Calculated performance curves for typical dynamic-braking lowering circuits are given as solid lines in Figures 1 and 2. Measured speed–torque values are indicated by dots.

Analysis of the deviation between calculated and test data indicates that, for a given amount of overhauling torque, calculated speed values are within 0.03 per unit of measured speed values. Since practical applications generally require that calculated performance curves be within 0.05 per unit of actual performance, the conclusion is drawn that the conventional method of calculating series motor performance obtains adequate practical data.

Test results demonstrate that calculated performance curves obtain a good indication of the approach of stability limit, that is, the maximum overhauling torque the motor is capable of retarding. Calculating motor performance by determining voltage and current in the motor circuit branches and then calculating speed and torque with the aid of $K$ factors, one obtains data which are entirely adequate for designing crane-hoist controllers.

Digest of paper **49-138**, "Dynamic Braking Control of D-C Series Motors—Experimental Study of Speed–Torque Curves," recommended by the AIEE Industrial Control Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Codes and Translations

OSCAR MYERS

ONE OF the problems which confronted S. F. B. Morse when he undertook to transmit intelligence by means of his electric telegraph was to devise a code suitable to the electric circuit and mechanical apparatus which he had constructed. His solution was the familiar Morse code. The translators for encoding and decoding the electric signals were the telegraph operators. Alexander Graham Bell's telephone avoided the need for translations through the use of conversion devices having simple mathematical relationships between the voice signals and their electrical equivalents; but the discrete, arbitrary relationships which characterize code methods have made their appearance in pulse code modulation recently devised for microwave transmission; the translators in this case are electronic circuits working at tremendous speeds. This article, however, deals not with codes and translators for the transmission of the message itself, but with their use in switching systems for the purpose of setting up telephone connections. Here they have been developed in numerous and varied forms, both for sending telephone numbers or similar information from one central office to another, and also within a central office for signaling from one component of a switching system to another. The forms of the codes and the electrical methods for transmitting them vary with the nature of the information, the form of the apparatus involved, and the character of the signaling channel.

The first dial systems used the dial for coding the called number and step-by-step selectors, directly controlled by the dial, for setting up the connections. As the switching art progressed and the nomenclature and trunking problems of large multioffice cities were encountered, new groups of circuits called senders and translators were introduced for use between the dials and the switches. These circuits were capable of storing the dial pulses and translating them into new electrical codes for controlling large nondecimal switches.

The first system which used senders and translators was the panel system. In this system, the code digits which were dialed into the senders in a decimal pulse code were changed into a nondecimal "revertive" code in which the translator set the sender to count a predetermined series of control pulses coming back from the distant selectors. The sender could also change part or all of the dialed code into a "call indicator" code for operating a bank of call indicator lamps to give a visual display of the called number at an operator's position in a manual office. The panel system also used a key pulsing code for registering in a sender the called office designation and number, which were keyed by an operator using a 10-button key set.

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Further development of the switching art has resulted in the introduction of crossbar switching systems which employ more coding and translation than the panel system. Examples are presented in the order in which they might be encountered on a normal call.

When a subscriber lifts his receiver one of a group of senders or registers is temporarily attached to his line to record the dialed number. As he dials, he produces a series of line breaks in which the digital value corresponds to the number of breaks except for the digit zero which is ten breaks. A relay circuit counts these breaks, transforms the decimal code into a "two out of five" code in which the called number is stored on relays. Coding and simple forms of translation are involved in this process.

A more complicated form of translation is used in setting up a connection to a trunk as the result of receiving the code of the called office. This translation is accomplished by an originating marker, which is one of a group of common control circuits called into action for a fraction of a second per call to change the called office code into combinations of signals to be used partly in setting up the switches for connecting the line to a trunk. This translation is a process of reducing the 3-digit decimal code to a "code point" and then expanding the "code point" into the several required control items by means of relays and wire cross-connections.

Codes and translations are also used at the terminating office in setting up the connection between the incoming trunk and the called line. Information is sent from the originating office to the terminating office by one of several types of coded pulses, as, for example, pairs of frequencies. At the terminating offices the pairs of frequencies are detected, changed in form, and presented to a terminating marker which is in part a called number translator. Terminating markers are in a common pool and a marker is associated with a terminating sender for a fraction of a second on each call to set up the connection to the called line. Coded information representing the four decimal digits of the called station is presented to the marker which proceeds to translate these digits into new forms required by the terminating equipment of the switching machine. The called number is turned into data for locating the line equipment, for setting up the required ringing code, and into numerous other items needed in setting up the call or for contingencies.

Automatic switching is now being extended to the toll plant. Problems met in this connection have, in general, been solved by an extension of the coding and translating mechanisms already employed in local systems. Future developments will undoubtedly be accompanied by improvements in translators which are becoming an increasingly important part of control mechanisms now being developed.

# New Frequency Assignments for Mobile-Radio Systems

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**This article describes the method by which a new operating frequency for each of the 500 mobile-radio systems (25,000 transmitters) operated by licensees under the Power Radio Service will be selected and recommended to the Federal Communications Commission for assignment and use not later than July 1, 1950. The basic principles, conceived in March 1947 by the author, then Sponsor Representative of the Edison Electric Institute on the Radio Technical Planning Board and a member of Committee 4 of RTPB Panel 13, have been expanded and refined by a subcommittee of the National Committee for Utilities Radio of which the author was Chairman. The plan has been commended by the Commission and recommended to the consideration of other mobile services.**

SINCE 1947 the operators of mobile-radio systems have been faced with the certain prospect of a drastic revision of their frequency assignment patterns. This prospect materialized with the recent reclassification of all mobile services and the concurrent recasting of frequency reallocations by the Federal Communications Commission.

The Power Radio Service (electric, gas, water, and steam utilities) was one of those involved in the change and the National Committee for Utilities Radio was faced with the task of developing a plan for the collective industries which would at once alleviate the severe interference being experienced and provide for the future expansion of the service under conditions which would secure to all users a maximum effectiveness in their use of radio facilities.

The successful completion of this task involved two major steps. The first was the preparation of a national pattern aimed at minimizing *F* layer skip and sporadic *E* transmissions through co-ordinated geographic control of assignments. The second was the development of a uniform method of selecting the most suitable frequency for each individual system considering not only the national pattern, but also the local requirements. A prerequisite of the national pattern was the nationwide availability of all allocated frequencies.

## THE NATIONAL PATTERN

The first essential in any plan of geographic control is the delineation of control zones. For purposes of local administrative convenience, the Radio Technical Planning Board Power Utilities Committee (*C4 P13*) had divided the United States into ten regions of roughly equal size. With minor modifications in boundaries, these ten regions were found to be suited to the need for frequency control zones. These ten zones were labelled from *A* to *J* for identification and are shown in Figure 1.

The committee had also collected information on the number of systems and the number of transmitters which were expected to be in operation by 1951, in each of the ten regions. From regional maps on which the base stations of each of these systems had been spotted, the approximate load-center of each zone was determined by inspection and all of the interzone load-center distances were scaled off. The total number of transmitters (base and mobile) expected to be in operation at both ends of each interzone path by 1951 was then determined. These were tabulated as indexes of the number of stations which might be exposed to skip interference over the respective paths. These two sets of data are shown in Table I.

The curves of interference duration factors given in Figure 2 express the fact that, within the limits of the continental United States, the percentage of time during which *F* layer skip interference (and the same is true for sporadic *E* interference) may be expected to occur, increases as the separation between receiver and interfering transmitter increases. Since only relative values are used herein, no attempt has been made to insure the accuracy of the absolute values shown in Figure 2. Interference duration

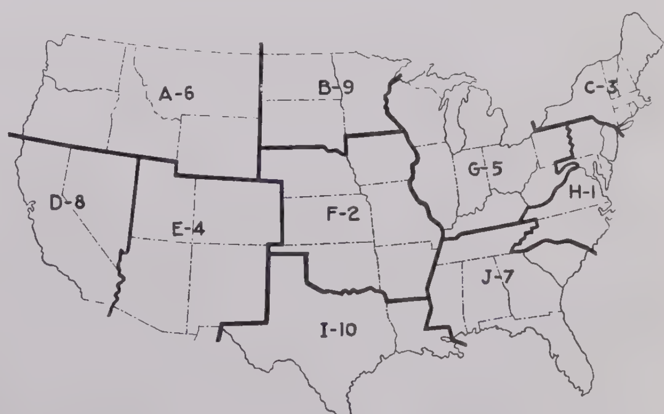


**Figure 1. Frequency control zones and prime frequency assignment pattern—Power Radio Service**

*Letters are arbitrary zone designations. Numbers represent specific frequencies in a block sequence of ten channels*

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The author acknowledges the assistance of the many members of the National Committee for Utilities Radio, in particular, J. G. McKinley, W. C. Phillips, and M. K. Patterson, all of whom made major contributions to the final plan.

**Table I. Loading and Distance Factors for Frequency Zones of Power Radio Service**

| Total 1951 Transmitters in Both Zones (Thousands) — Zone | Load-Center Distances Hundreds of Miles — A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A | **1.4** | 8 | 21 | 8 | 6 | 13 | 17 | 22 | 14 | 20 |
| B | 2.2 | **0.8** | 13 | 14 | 9 | 5 | 7 | 12 | 10 | 11 |
| C | 3.6 | 3.0 | **2.2** | 25 | 19 | 12 | 7 | 4 | 15 | 10 |
| D | 2.9 | 2.3 | 3.7 | **1.5** | 6 | 14 | 18 | 23 | 13 | 20 |
| E | 2.2 | 1.6 | 3.0 | 2.3 | **0.8** | 8 | 12 | 17 | 7 | 14 |
| F | 3.8 | 3.2 | 4.6 | 3.9 | 3.2 | **2.4** | 5 | 9 | 5 | 7 |
| G | 8.4 | 7.8 | 9.2 | 8.5 | 7.8 | 9.4 | **7.0** | 5 | 9 | 7 |
| H | 3.5 | 2.9 | 4.3 | 3.6 | 2.9 | 4.5 | 9.1 | **2.1** | 12 | 6 |
| I | 3.9 | 3.3 | 4.7 | 4.0 | 3.3 | 4.9 | 9.5 | 4.5 | **2.5** | 7 |
| J | 3.9 | 3.3 | 4.7 | 4.0 | 3.3 | 4.9 | 9.5 | 4.6 | 5.0 | **2.5** |

The diagonal shows the number of 1951 transmitters in each zone.

**Table II. Interference-Duration Factors for Frequency Zones of Power Radio Service**

| For 47 Megacycles — Zone | For 37 Megacycles — A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A | | 2.73 | 6.99 | 2.73 | 0.74 | 6.41 | 6.92 | 6.99 | 6.62 | 6.98 |
| B | 0.160 | | 6.41 | 6.62 | 3.85 | 0.21 | 1.61 | 6.02 | 4.76 | 5.53 |
| C | 0.998 | 0.820 | | 7.00 | 6.97 | 6.02 | 1.61 | 0.03 | 6.76 | 4.76 |
| D | 0.160 | 0.885 | 1.000 | | 0.74 | 6.62 | 6.95 | 7.00 | 6.41 | 6.98 |
| E | 0.016 | 0.298 | 0.992 | 0.016 | | 2.73 | 6.02 | 6.92 | 1.61 | 6.62 |
| F | 0.820 | 0.002 | 0.724 | 0.885 | 0.160 | | 0.21 | 3.85 | 0.21 | 1.61 |
| G | 0.975 | 0.063 | 0.063 | 0.986 | 0.724 | 0.002 | | 0.21 | 3.85 | 1.61 |
| H | 0.999 | 0.724 | 0.000 | 0.999 | 0.975 | 0.298 | 0.002 | | 6.02 | 0.74 |
| I | 0.885 | 0.450 | 0.930 | 0.820 | 0.063 | 0.002 | 0.298 | 0.724 | | 1.61 |
| J | 0.996 | 0.060 | 0.450 | 0.996 | 0.885 | 0.063 | 0.063 | 0.016 | 0.063 | |

These values are taken directly from Figure 2 and correspond to the load-center distances shown in Table I (upper right section).

values corresponding to the interzonal load-center distances of Table I were taken from these curves and tabulated in Table II. Multiplication of these interference-duration factors by the corresponding loading factors of Table I resulted in the interference-severity factors shown in Table III. These values have no absolute significance but do indicate the relative order of skip interference severity (as measured by length of time experienced not by instantaneous signal strength) which systems operating cochannel in any two of the zones might expect to experience.

For purposes of simplified illustration let it now be assumed that ten frequencies have been allocated to a service and that these are available for assignment within all zones.

As the first step in the development of a co-ordinated pattern, let it be further assumed that the ten frequencies are divided among the ten zones—the one assigned to each being identified as the "prime" frequency of that zone. The factors shown in Table III then provide a reasonable basis for varying the concentration of assignments on the prime frequency of each zone in all other zones. Taking zone *G* for example, its 47-megacycle interference severity factors from Table III may be arranged in ascending order, to create the following sequence list:

| | |
|---|---|
| Zone *G*—0.00 | Zone *J*—0.60 |
| Zone *H*—0.02 | Zone *I*—2.83 |
| Zone *F*—0.02 | Zone *E*—5.65 |
| Zone *B*—0.49 | Zone *A*—8.19 |
| Zone *C*—0.58 | Zone *D*—8.38 |

By concentrating the use of zone *G*'s prime frequency in the top zones as listed and as far as possible avoiding the use of it in the bottom zones, a situation conducive to the reduction of skip interference will have been created. If assignments on zone *G*'s prime frequency had been proportionately spread over all zones, the same total number of assignments probably would have resulted but those systems which occupied it in zone *D*, for example, would have been subjected to and created three times as much skip interference as those cochannel systems in zone *I*, and 17 times as much as those in zone *B*.

Restating the process from the viewpoint of zone *G*, the desired result will be achieved if assignments within zone *G* are made by: first, concentrating as many systems as possible on the prime frequency of zone *G;* secondly, concentrating as many remaining systems as possible on the prime frequency of zone *H;* thirdly, using the prime frequencies of zones *F*, *B*, *C*, and so forth, in that order; and lastly, making the fewest possible assignments (preferably none) on the prime frequencies of zones *E*, *A*, and *D*.

In effect, this method of decreasing the zonal occupancy of each channel in the reverse order of its interference severity factor, leaves all frequencies available in all zones and merely specifies for each specific zone the relative desirability of each frequency from a skip interference standpoint.

To complete the national pattern there remained the problem of how to assign specific prime frequencies to the ten zones. Obviously, if a satisfactory pattern could be developed for a block of ten consecutive frequencies, it could be repeated using whole and fractional blocks until all frequencies allocated had been assigned to the ten zones as prime frequencies.

This problem was attacked on a trial and error basis aiming at the following objectives, the alternate channel requirement being imposed by the technical limitations of the majority of the equipment presently in service:

1. In no case should geographically adjacent zones be assigned

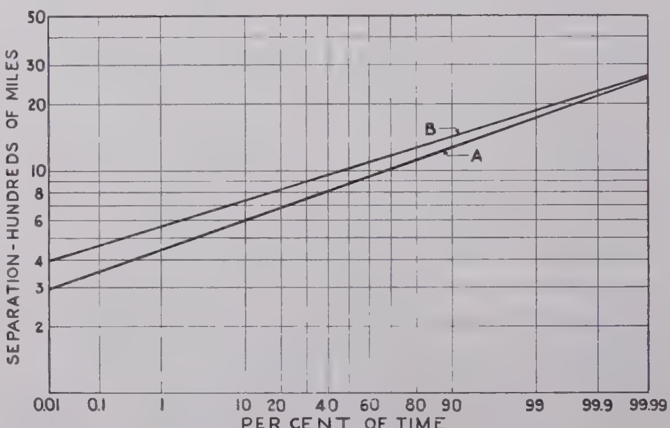


**Figure 2. Estimated duration of F-layer skip interference 6 a.m. to midnight; worst ionospheric conditions**

*A—37-megacycle frequencies; multiply per cent of time scale by 0.07 to convert to per cent of actual time*

*B—48-megacycle frequencies; multiply per cent of time scale by 0.01 to convert to per cent of actual time*

*Both curves are rough approximations derived from estimates by Allen (Proceedings, Institute of Radio Engineers, February 1947) and Norton (Federal Communications Commission docket 6651) for relative comparisons only*

Table III. Interference Severity Factors for Frequency Zones of Power Radio Service

| Zone | | For 37 Megacycles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J |
| For 47 Megacycle A | | 6.01 | 25.16 | 7.92 | 1.62 | 24.36 | 58.13 | 24.47 | 25.82 | 27.22 |
| B | 0.35 | | 19.23 | 15.23 | 6.16 | 0 67 | 12.56 | 17.46 | 15.71 | 18.25 |
| C | 3.59 | 2.46 | | 25.90 | 20.91 | 27.69 | 14.81 | 0.13 | 31.77 | 22.37 |
| D | 0.46 | 2.04 | 3.70 | | 1.69 | 25.82 | 59.08 | 25.20 | 25.64 | 27.92 |
| E | 0.04 | 0.48 | 2.98 | 0.04 | | 8.74 | 46.96 | 20.07 | 5.31 | 21.85 |
| F | 3.12 | 0.01 | 3.33 | 3.45 | 0.51 | | 1.97 | 17.33 | 1.03 | 7.89 |
| G | 8.19 | 0.49 | 0.58 | 8.38 | 5.65 | 0.02 | | 1.91 | 36.58 | 15.30 |
| H | 3.50 | 2.10 | 0.00 | 3.60 | 2.83 | 1.34 | 0.02 | | 27.09 | .08 |
| I | 3.45 | 1.49 | 4.37 | 3.28 | 0.21 | 0.01 | 2.83 | 3.26 | | 3.53 |
| J | 3.88 | 1.98 | 2.12 | 3.98 | 2.92 | 0.31 | 0.60 | 0.07 | 0.32 | 8 |

These values are the products of the loading factors (lower left part of Table I) and the 37-megacycle interference-duration factors of Table II.

Table IV. Co-ordination Sequence List of Ten Arbitrary Channels Assigned as Prime Frequencies to Ten Zones

| Co-ordination Sequence | Zone A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1st | 6 | 9 | 3 | 8 | 4 | 2 | 5 | 1 | 10 | 7 |
| 2d | 4 | 2 | 1 | 4 | 8 | 10 | 1 | 3 | 2 | 1 |
| 3d | 9 | 6 | 5 | 6 | 6 | 9 | 2 | 5 | 4 | 2 |
| 4th | 8 | 4 | 7 | 9 | 10 | 5 | 9 | 7 | 7 | 10 |
| 5th | 2 | 5 | 9 | 10 | 9 | 7 | 3 | 2 | 9 | 5 |
| 6th | 10 | 10 | 4 | 2 | 2 | 4 | 7 | 9 | 5 | 9 |
| 7th | 1 | 7 | 2 | 1 | 1 | 1 | 10 | 4 | 1 | 3 |
| 8th | 3 | 8 | 6 | 3 | 7 | 6 | 4 | 10 | 8 | 4 |
| 9th | 7 | 1 | 8 | 7 | 3 | 3 | 6 | 6 | 6 | 6 |
| 10th | 5 | 3 | 10 | 5 | 5 | 8 | 8 | 8 | 3 | 8 |
| Total available alternate frequencies | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5=47 |
| Same in top half of pattern | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4=41 |

spectrally adjacent frequencies. To do so would not only create serious conflicts along the common geographic boundary, but would also force the occupancy of frequencies farther down on the sequence list and therefore less desirable.

2. The pattern should provide each zone with the maximum possible number of alternate channels.

3. As many as possible of these alternate channels should be located in the top half of each zone sequence list.

The final result of numerous trials is a pattern (Figure 1) which contains no prime channel adjacencies and closely approaches the second and third objectives. Table IV shows the sequence lists for each zone as developed from data in Table III (47-megacycle section) and Figure 1. For the ten zones an average of 4.7 available alternate channels out of a maximum possible of five has been achieved, 4.1 of these being located in the top half of the sequence list. No zone has less than four alternate channels available in the top half of its list.

A pattern for ten 37-megacycle channels was developed in precisely the same manner using the interference severity factors applicable to the lower frequency but omitting, as unassignable frequencies, the prime frequencies of the two zones which occupied the two bottom positions on the sequence list of each zone. A combination of the two patterns thus developed, but expanded to cover 30 of the channels allocated to the Power Radio Service is given in Table V. This is the actual pattern presently being used by the ten Regional Frequency Co-ordination Committees which were created by the National Committee for Utilities Radio at the request of the Federal Communications Commission, to assist the latter by making recommendations for individual frequency assignments.

## THE REGIONAL PATTERN

While the national pattern provides each Regional Frequency Co-ordination Committee with a sequence list which, as explained in the foregoing, shows for its specific region all of the allocated frequencies arranged in order of their desirability from the standpoint of skip interference, it does not and obviously cannot deal with individual system assignments. Before these can be arrived at, the regional committee must consider the matters of ground wave and tropospheric interference. To aid the former consideration the National Committee for Utilities Radio developed a simple procedure which has been uniformly and successfully applied by all of the ten regional groups.

It is well known that the factor which normally limits the geographic spacing between cochannel, adjacent channel, and alternate channel system assignments is the strength of an unwanted signal received from the base station transmitter of an adjoining system at the base station receiver of the home system. The values shown in Table VI were adopted as reasonable norms in this situation. By applying to these the techniques and data of Bullington and others,[1] it was a simple matter to develop the normal minimum base station spacings shown in Table VII.

Supplied with these, the first step undertaken by a regional committee in making up an assignment pattern for, say, the 30/50-megacycle band, was the preparation of a large scale map of the region (including all territory

Table V. Zone Frequencies and Sequence of Use—Power Radio Service

| | Zone A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| **Zone Frequencies (Megacycles)** | | | | | | | | | | |
| 1 | 48.34 | 48.46 | 48.22 | 48.42 | 48.26 | 48.18 | 48.30 | 48.14 | 48.50 | 48.38 |
| 2 | 47.94 | 48.06 | 47.82 | 48.02 | 47.86 | 47.78 | 47.90 | 47.74 | 48.10 | 47.98 |
| 3 | 37.66 | 37.54 | 37.78 | 37.58 | 37.74 | 37.82 | 37.70 | 37.86 | 37.50 | 37.62 |
| **Use Sequence** | | | | | | | | | | |
| 1st | A1 | B1 | C1 | D1 | E1 | F1 | G1 | H1 | I1 | J1 |
| | A2 | B2 | C2 | D2 | E2 | F2 | G2 | H2 | I2 | J2 |
| | A3 | B3 | C3 | D3 | E3 | F3 | G3 | H3 | I3 | J3 |
| 2d | E2 | F2 | H2 | E2 | D2 | I2 | H2 | C2 | F2 | H2 |
| | E1 | F1 | H1 | E1 | A2 | B2 | F2 | C1 | F1 | H1 |
| | E3 | F3 | H3 | E3 | A3 | B3 | H3 | C3 | F3 | H3 |
| 3d | B2 | A2 | G2 | A2 | D1 | I1 | H1 | G2 | E2 | F2 |
| | B1 | A1 | G1 | A1 | A1 | IB1 | F1 | G1 | E1 | F1 |
| | B3 | A3 | G3 | A3 | D3 | G3 | F3 | G3 | E3 | I3 |
| 4th | D2 | E2 | J2 | B2 | I2 | G2 | B2 | J2 | J2 | I2 |
| | D1 | E1 | J1 | B1 | I1 | 11 | B1 | J1 | J1 | I1 |
| | D3 | E3 | B3 | B3 | I3 | G3 | B3 | J3 | J3 | F3 |
| 5th | F2 | G2 | B2 | I2 | B2 | J2 | C2 | F2 | B2 | G2 |
| | F1 | G1 | B1 | I1 | B1 | J1 | C1 | F1 | B1 | G1 |
| | F3 | G3 | E3 | H3 | B3 | J3 | C3 | F3 | B3 | G3 |
| 6th | I2 | I2 | E2 | F2 | F2 | E2 | J2 | B2 | G2 | B2 |
| | I1 | I1 | E1 | F1 | F1 | E1 | J1 | B1 | G1 | B1 |
| | H3 | D3 | J3 | F3 | F3 | E3 | J3 | B3 | A3 | B3 |
| 7th | H2 | J2 | F2 | H2 | H2 | H2 | I2 | E2 | H2 | C2 |
| | H1 | J1 | F1 | H1 | H1 | H1 | I1 | E1 | H1 | C1 |
| | C3 | I3 | A3 | I3 | H3 | H3 | I3 | E3 | D3 | E3 |
| 8th | C2 | D2 | A2 | C2 | J2 | A2 | E2 | I2 | D2 | E2 |
| | C1 | D1 | A1 | C1 | J1 | A1 | E1 | I1 | D1 | E1 |
| | I3 | H3 | D3 | C3 | C3 | A3 | E3 | A3 | H3 | C3 |
| 9th | J2 | H2 | D2 | J2 | C2 | C2 | A2 | A2 | A2 | A2 |
| | J1 | H1 | D1 | J1 | C1 | C1 | A1 | A1 | A1 | A1 |
| 10th | G2 | C2 | I2 | G2 | G2 | D2 | D2 | D2 | C2 | D2 |
| | G1 | C1 | I1 | G1 | G1 | D1 | D1 | D1 | C1 | D1 |

**Table VI. Basic Conditions Assumed to Exist on the Normal Power Utility Mobile Radio System**

| | | |
|---|---|---|
| Base station power | 250 watts | |
| Base station antenna height (effective) | 100 feet | |
| Base station antenna gain (30/50 megacycles) | 1.0 | |
| Base station antenna gain (152/162 megacycles) | 3.0 | |
| Minimum strength of desired signal at terminals of base station receiver | 1 microvolt | |
| Maximum permissible strength of undesired signal at same point | 0.5 microvolt | |
| Base receiver attenuations* | 30/50 megacycles | 152/162 megacycles |
| On adjacent channel carrier (40/60 kc off) | 35 decibels | 45 decibels |
| On alternate channel carrier (80/120 kc off) | 70 decibels | 85 decibels |
| Intervening shadow losses | none | |
| Earth radius equivalent | 4/3 | |

* Gives recognition to the fact that a high percentage of the receivers now in service are not of the most modern design.

**Table VII. Minimum Geographic Spacings Normally Permissible Between Base Stations in the Power Radio Service**

| | 30/50 Megacycles | 152/162 Megacycles |
|---|---|---|
| Cochannel operation | 100 miles | 75 miles |
| Adjacent channel operation | 50 miles | 35 miles |
| Alternate channel operation | 10 miles | 5 miles |

for 100 miles beyond the regional boundaries) showing all existing and proposed base stations, each keyed with a number indicating ownership. A transparent template on which three concentric circles of 10-, 50-, and 100-mile map scale radius had been inscribed was then placed over each base station in turn, and a tabulation (see Table VIII) was made of the required spectrum separation in channels (3, 2, 1, or 0) as indicated by the circle or annular ring on the template within which each foreign base station fell. Only systems were tabulated and where more than one base station per system was encountered, the maximum separation required by any such base station was used. In the larger congested regions this process involved more than 2,000 individual determinations for 50 to 75 systems.

With these tabulations completed, the vertical columns were totalled and the sums used as a co-ordinating index showing the comparative difficulty which would be experienced in co-ordinating each system with all others in the region.

Table IX illustrates the final step in the assignment process as it would be worked out assuming that the hypothetical data of Table VIII applied to zone *C*. Here, for simplicity, only ten 48-megacycle channels have been listed, together with their sequence numbers. The systems have been arbitrarily numbered and listed in order of their co-ordinating indexes. System 8 has the highest index and since this usually (but not necessarily) denotes an extensive system with multiple base stations, it is assigned to the prime channel of the zone which is 48.22 megacycles. System number 9 is then considered and reference to Table VIII shows that its frequency must be two channels away from that of system 8. The frequency of 48.18 megacycles occupies number two position on the list for the area and since it is two channels removed from 48.22-megacycles, system number 9 is assigned to it. Taking system number 4 next, it is seen from Table VIII that its frequency must be two channels away from that of both system 8 and system 9. Channel 3 on the sequence list (48.30 megacycles) is so located and system 4 is accordingly assigned to it. System 5 must be two channels from system 8, one channel from system 9, and two channels from system 4. It must, therefore, occupy number 4 position on the sequence list (48.38 megacycles). System 3 could be placed cochannel with system 8 in the number 1 sequence position were it not for the requirement that it be three channels removed from system 4. To meet this, it must be placed on 48.18 megacycles (sequence position 7). Following this method for all of the remaining systems and placing each as close to the top of the sequence list as possible, the pattern may be completed as shown. It must then be co-ordinated with the patterns of neighboring regions and all conflicting assignments resolved by making revisions in the patterns of one or both regions.

## PRACTICAL CONSIDERATIONS

The foregoing description has adhered closely to theoretical processes. In working out the actual regional plans, many local problems arose which required the exercise of considerable judgment on the part of the regional committee whose collective major qualification is a thorough knowledge of local conditions. Variations from normal conditions due to mountain-top antennas, power differences, directional antennas, local topography, unusual tropospheric conditions along coastal areas, and so forth. had to be allowed for, and this was usually done at the stage where the required system separations in channels were transferred from maps to tabular form (Table VIII); the

**Table VIII. Sample Tabulation of Required Channel Separations**

| System Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| 3 | 0 | 0 | | 3 | 3 | 0 | 0 | 0 | 1 | 0 |
| 4 | 0 | 0 | 3 | | 2 | 0 | 0 | 2 | 2 | 0 |
| 5 | 0 | 0 | 3 | 2 | | 0 | 0 | 2 | 1 | 0 |
| 6 | 0 | 1 | 0 | 0 | 0 | | 0 | 2 | 2 | 2 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | | 2 | 0 | 0 |
| 8 | 0 | 2 | 0 | 2 | 2 | 2 | 2 | | 2 | 0 |
| 9 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 2 | | 2 |
| 10 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | |
| Total | 0 | 3 | 7 | 9 | 8 | 7 | 2 | 12 | 10 | 4 |
| Assignment Order | 10 | 8 | 5 | 3 | 4 | 6 | 9 | 1 | 2 | 7 |

**Table IX. Sample Determination of Frequency Assignments, Zone C**

| Frequency | 48.14 | 48.18 | 48.22 | 48.26 | 48.30 | 48.34 | 48.38 | 48.42 | 48.46 | 48.50 |
|---|---|---|---|---|---|---|---|---|---|---|
| Sequence Number | 2 | 7 | 1 | 6 | 3 | 8 | 4 | 9 | 5 | 10 |
| System Number | | | | | | | | | | |
| 8 | | | X | | | | | | | |
| 9 | X | | | | | | | | | |
| 4 | | | | | X | | | | | |
| 5 | | | | | | | X | | | |
| 3 | | X | | | | | | | | |
| 6 | | | | | X | | | | | |
| 10 | | | X | | | | | | | |
| 2 | X | | | | | | | | | |
| 7 | X | | | | | | | | | |
| 1 | | | X | | | | | | | |

Frequencies are listed in order of spectrum location.

Sequence numbers are obtained from Table V.

Systems are listed by assignment order from Table VIII.

basic separations being either increased or decreased by one channel as required in individual cases. In a few instances, particularly when considering the 152/162-megacycle band in the vicinity of major metropolitan centers, it was necessary to make an across-the-board reduction of one channel in order to accommodate all systems on the inadequate number of channels allocated to the service in this band. This will require all new users to purchase narrow-band 152/162-megacycle equipment and in some cases may make it necessary for a few present users to replace some equipment.

As new systems apply for assignments, their base stations can be plotted, their channel separation from all other systems entered in the basic tabulation, and a determination of the most suitable frequency made within an hour or two. There will be no guess work or uncertainty as to whether some other frequency would be more a suitable assignment.

In its broad aspects, the plan described represents a nationwide co-operative and impartial attempt, on the part of all groups which make up the Power Radio Service, to bring order out of chaos at a particularly opportune time, and to provide a logical guide for the future expansion of a most valuable aid to utility operations in a manner which will insure its greatest over-all usefulness. To this end the National Committee for Utilities Radio is co-operating with the Federal Communications Commission by making its studies and recommendations available to the latter, in whom rests the statutory responsibility for all frequency assignments.

REFERENCE

1. Radio Propagation at Frequencies Above 30 Megacycles. *Proceedings*, Institute of Radio Engineers (New York, N. Y.), October 1947, pages 1122–36.

# Proposed Changes in Transformer Standards

AN AIEE COMMITTEE REPORT

**A tentative Standard for trial use for a period of one year and various changes in Standards covering short-circuit requirements and limiting temperatures are proposed in this progress report of the AIEE Transformer Committee which originally was presented at the 1949 Summer General Meeting in Swampscott, Mass.**

IN ONE of the transformer sessions at Swampscott, Mass., during the 1949 AIEE Summer General Meeting there was presented a progress report containing proposed changes in the transformer Standards which had been favorably acted upon during the year preceding the meeting. At the meeting of the Transformer Committee it was decided to publish these proposed changes and to suggest that they be put into use at once without waiting for them to be processed by the American Standards Association.

These are as follows:

1. Tentative Standard suggested for trial use for a period of one year.

Insert 110 degrees centigrade in the column of Table 11.021 giving hottest-spot temperature rise for class *B* insulation and modify it by the following note:

"A value of 110 degrees centigrade was agreed upon by the Working Group of Subject 6 and was accepted by the Transformer Committee as a tentative limiting hot-spot temperature rise for dry-type transformers insulated with class *B* insulation. There was considerable difference of opinion among the members of the working group and of the main committee as to what values should be used for the hottest spot temperature rise. Values considerably higher and lower than 110 degrees centigrade were suggested based on the experience and judgment of different individuals. Some consider the value of 110 degrees centigrade extremely conservative; others consider it as being higher than is justified by the available data. Accordingly, this value represents a compromise figure to be used as a tentative value subject to the results of the study of the aging characteristics of class *B* insulating materials which has been assigned to one of the other working groups of the Transformer Committee."

2. Changes in Standards covering short-circuit requirements and corresponding limiting temperatures as indicated in the following paragraphs.

12.050. PERMISSIBLE SHORT CIRCUITS

Change paragraph 12.050 and paragraph 12.051 in ASA-C57 to read as follows:

1. Transformers shall be capable of withstanding without injury short circuits on any external terminals,

Full text of a progress report of the AIEE Transformer Committee, originally presented at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. The present report was compiled by J. E. Clem, Chairman of the Subcommittee on Papers of the Transformer Committee, who is in the Central Station Engineering Divisions, General Electric Company, Schenectady, N. Y.

**Personnel of AIEE Transformer Committee for 1948–49:** H. B. Keath (*Chairman*), J. A. Adams, F. S. Brown, M. K. Brown, R. J. Brown, J. L. Cantwell, J. H. Chiles, J. E. Clem, G. W. Clothier, Merrill DeMerit, J. A. Elzi, M. M. Ewell, I. W. Gross, J. B. Hodtum, W. G. James, A. A. Johnson, D. L. Levine, H. C. Louis, C. M. Lovell, V. M. Montsinger, M. H. Pratt, T. D. Reimers, W. C. Sealey, F. L. Snyder, Paul A. Vance, F. J. Vogel, C. V. Waddington, H. H. Wagner, C. E. Winegartner.

with rated line voltages maintained on all terminal intended for connection to sources of power, provided:

(*a*). The magnitude of the symmetrical current in any winding of the transformer, resulting from the external short circuit, does not exceed 25 times the base current, as defined in paragraphs 3 and 4, of the winding. The initial current is assumed to be completely displaced from zero.

(*b*). The duration of the short circuit is limited to the following time periods. Intermediate values may be determined by interpolation.

| Symmetrical Current in Any Winding | Time Period in Seconds |
|---|---|
| 25 times base current | 2 |
| 20 times base current | 3 |
| 16.6 times base current | 4 |
| 14.3 or less times base current | 5 |

2. Where kilovolt-amperage is mentioned in paragraphs 3 and 4 the following is intended:

When the windings have a self-cooled rating, the kilovolt-amperage of the self-cooled rating shall be used. When the windings have no self-cooled ratings, the largest kilovolt-amperage obtained from the ratings assigned for other means of cooling, by the use of the following factors, shall be used:

| Type of Transformer | Multiplying Factor (Not Less Than) |
|---|---|
| Water-cooled | 1.0 |
| Dry-type forced-air-cooled | 0.75 |
| Forced-oil-cooled with either forced-air coolers or forced-water coolers | 0.60 |

3. For multiwinding transformers:

The base current of any winding provided with external terminals, or of any delta-connected stabilizing winding without terminals, shall be determined from the rated kilovolt-amperage of the winding or from not less than 35 per cent of the rated kilovolt-amperage of the largest windings of the transformers, whichever is larger.

4. For Y-Y connected autotransformers:

(*a*). The base current of the common winding shall be determined from the maximum kilovolt-amperage which the common winding may carry under conditions of simultaneous loading authorized by the name plate.

(*b*). The base current of the series winding is the rated current of that winding on the connection used or the current determined from not less than 35 per cent of the kilovolt-amperage of the common winding as determined in paragraph *a*, or from not less than 35 per cent of the rated kilovolt-amperage of the delta-connected winding, whichever of the three is the largest.

(*c*). The base current for a delta-connected stabilizing winding with or without external terminals shall be determined from its kilovolt-amperage rating or the current from not less than 35 per cent of the equivalent kilovolt-amperage of the autotransformer winding, whichever is larger. Equivalent kilovolt-amperage of autotransformer winding equals one-half the sum of the kilovolt-amperes of the series and common windings from which the base currents as described in paragraphs *a* and *b* are derived.

5. The combined impedance of transformers and directly connected apparatus shall be considered as limiting the short-circuit current of transformers which are connected in series with other apparatus possessing inherent impedance, located only a few feet from the transformers, and so connected to them that there is no practical possibility of loss of this additional series impedance.

In some instances, the short-circuit current, as limited by transformer impedance alone, will exceed 25 times base current. It must be recognized that such cases can occur with transformers manufactured according to these Standards and that the transformers built under these Standards are not designed to withstand such short-circuit current.

12.051. TEMPERATURE LIMITS FOR SHORT-CIRCUIT CONDITIONS

The temperature, as computed by the formula in 22.105, of the copper in the windings of distribution, power, and regulating transformers and reactors (other than current-limiting or neutral-grounding reactors), under the short-circuit conditions given in 12.050, shall not exceed:

1. 250 degrees centigrade where class *A* insulation is used assuming an initial temperature of:

(*a*). 95 degrees centigrade for windings that are designed to carry load.

(*b*). 75 degrees centigrade for windings that are not designed to carry load, such as stabilizing windings.

2. 350 degrees centigrade where class *B* insulation is used assuming an initial temperature of 130 degrees centigrade.

3. 500 degrees centigrade where class *H* insulation is used, assuming an initial temperature of 180 degrees centigrade.

# High-Speed Electronic Tachometer

A new tachometer which measures the speed of rotating machinery by counting electric impulses has been developed by the General Electric Company. The equipment consists of a high-frequency pulse generator or pickup, an electronic counting circuit, and two speed-indicating units, one for on-the-spot and the other for remote readings. The pulse counter measures speeds in the range of 0–17,000 rpm.

Any system which generates electric impulses may be used. In one method, a magnetic pulse generator fits on the periphery of a drum which is attached to the shaft of the machine to be tested. The drum is magnetized, one side containing 150 magnetic poles and the other side 1,500. When rotated, the drum generates electric impulses in the magnetic pickup which are carried to the electronic circuit, and there counted at speeds up to 50,000 cycles per second. The indicators flash the number of revolutions per minute on a screen, the figures changing every second to show variations in speed.

Up to 4,000 rpm, the 1,500-pole side of the generator is used with an accuracy to 0.1 rpm, while over 4,000 rpm, the pick-up shifts to the 150-pole side, the readings being accurate to 1 rpm. More information on this tachometer is contained in Publication GEC-560, which is available from the General Electric Company, Schenectady 5, N. Y.

# Vector Power Factor of 3-Phase Circuits

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THE VECTOR power factor is a quantity which has been officially defined in the Standards of the American Standards Association[1] and is the basis for many power rates which include lower power factor penalties. The effect of the unbalance in a polyphase load on this quantity can be analyzed by the method of symmetrical components.

Suppose that we consider a 4-wire unbalanced 3-phase load in which $\boldsymbol{E}_1$, $\boldsymbol{E}_2$, $\boldsymbol{E}_0$, and $\boldsymbol{I}_1$, $\boldsymbol{I}_2$, and $\boldsymbol{I}_0$ are the respective positive, negative, and zero sequence components of the phase voltages and currents. We shall define unbalance factors as the scalar quantities.

$$\left.\begin{array}{l} K_{2i}=I_2/I_1 \text{ and } K_{0i}=I_0/I_1 \text{ for current} \\ K_{2v}=E_2/E_1 \text{ and } K_{0v}=E_0/E_1 \text{ for voltage} \\ K_2=K_{2i}K_{2v} \text{ and } K_0=K_{0i}K_{0v} \text{ for combined unbalance factor} \end{array}\right\} \quad (1)$$

Let $\theta_1$, $\theta_2$, and $\theta_0$ be the phase angles between the sequence voltages $\boldsymbol{E}_1$, $\boldsymbol{E}_2$, and $\boldsymbol{E}_0$ and their respective sequence currents $\boldsymbol{I}_1$, $\boldsymbol{I}_2$, and $\boldsymbol{I}_0$. Then the vector volt-amperes of the unbalanced load can be expressed as[2]

$$P+jQ=3\,\boldsymbol{E}_1{}^*\boldsymbol{I}_1+\boldsymbol{E}_2{}^*\boldsymbol{I}_2+3\boldsymbol{E}_0{}^*\boldsymbol{I}_0 \quad (2)$$

where $\boldsymbol{E}_1{}^*$, $\boldsymbol{E}_2{}^*$, and $\boldsymbol{E}_0{}^*$ are the conjugates of the vector voltages $\boldsymbol{E}_1$, $\boldsymbol{E}_2$, and $\boldsymbol{E}_0$.

The left-hand side of equation 2, and hence also the magnitudes of $P$ and $Q$, can be rewritten to include a common factor 3 $E_1I_1$, and terms involving the unbalance factors defined by the equations in expression 1, together with sine and cosine functions of $\theta_1$, $\theta_2$, and $\theta_0$. If these magnitudes for $P$ and $Q$ are substituted into the formula for vector power factor, and the resulting expression simplified, the value of the vector power factor $\Lambda_v$, becomes

$$\Lambda_v=\frac{P}{\sqrt{P^2+Q^2}}=\frac{\cos\theta_1+K_2\cos\theta_2+K_0\cos\theta_0}{[1+K_2^2+K_0^2+2K_2\cos(\theta_1-\theta_2)+2K_0\cos(\theta_1-\theta_0)+2K_0K_2\cos(\theta_2-\theta_0)]^{1/2}} \quad (3)$$

Equation 3 gives the value of the vector power factor for a 3-phase 4-wire load for sinusoidal currents and voltages. For a 3-phase 3-wire load, the terms involving $K_0$ drop out and the expression reduces to

$$\Lambda_v=\frac{\cos\theta_1+K_2\cos\theta_2}{[1+K_2^2+2K_2\cos(\theta_1-\theta_2)]^{1/2}} \quad (4)$$

Equations 3 and 4 enable one to analyze the effects of various kinds of unbalance upon the magnitude of the vector power factor. It is readily seen that a current unbalance has the same effect as a voltage unbalance because $K_0$ and $K_2$ are the products of current and voltage unbalance factors. Conditions in which the vector power factor becomes numerically equal to cos $\theta_1$, the positive sequence power factor, are also easily recognized.

One interesting result to be noted is that the vector power factor appears to be independent of the time phases of the various sequence systems with respect to each other. For example, rotation of the negative sequence system with respect to the positive sequence system, will not affect the magnitude of the vector power factor since $\theta_1$, $\theta_2$, and $\theta_0$ are not affected by such a rotation.

In a 4-wire load, if the line voltages are balanced, $K_2$ becomes zero. However, $K_0$ is not necessarily zero, since a shift in the voltage neutral can occur even with no negative-sequence component in the line voltage. If $K_0$ is not zero, but $K_2$ is zero, then the power factor will reduce to an expression similar to equation 4 but involving $K_0$ and $\theta_0$ instead of $K_2$ and $\theta_2$.

For a 3-wire load, the vector power factor becomes equal to the positive-sequence power factor if either the line voltages or the line currents are balanced, or if the load consists of balanced static impedances. If the load consists of rotating machinery having an impedance to negative-sequence currents different from that to positive-sequence currents, an unbalance in voltage implies an unbalance in current and the complete expression in equation 4 must apply.

For most practical circuits, the unbalance factors $K_0$ and $K_2$ are small, since they are the products of current and voltage unbalance factors, each less than unity. Multiplication by cos $\theta_0$ or cos $\theta_2$ further reduces the magnitudes of some of the terms involved. Hence, even for badly unbalanced circuits, the vector power factor may often be approximately equal to cos $\theta_1$.

In this connection, another point should be noted. For high power factor loads, cos $\theta_1$ will be close to unity, and the unbalance terms will be small in comparison. For low power factor loads, cos $\theta_1$ will be small, and the unbalance terms will have a relatively greater importance in the determination of vector power factor. The fact that cos $\theta_0$, cos $\theta_2$, and so on, can be negative for many loads complicates the detailed analysis for this point.

It is evident that the relations developed in equations 3 and 4 make possible a clear conception of the different effects of various kinds of unbalance upon the vector power factor of a 3-phase load for sinusoidal applied voltages and currents. Experimental measurements taken on a number of unbalanced loads check equations 3 and 4 to a good degree of accuracy.

Digest of paper **49-123**, "The Vector Power Factor of Unbalanced Sinusoidal 3-Phase Circuits," recommended by the AIEE Basic Sciences Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE South West District Meeting, Dallas, Tex., April 19–21, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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1. American Standard Definitions of Electrical Terms. ASA Standard *C42-1941*, pages 43–6.

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# Relay "Trees" and Symmetric Circuits

S. H. WASHBURN

THE RELAY "tree," so-called because of its configuration, is a special case of a multiterminal network of relay contacts in which a single input terminal may be connected to one of a number of output terminals. The path from each output terminal to the input end of the network passes through contacts on all the relays upon which the network is constructed; and no paths can be connected together. The particular path closed through depends upon the combination of operated relays.

In the fully developed tree, there is an output terminal corresponding to each of the $2^n$ possible combinations of operated relays, where $n$ is the number of relays. A fully developed 4-relay tree, shown in Figure 1, has $2^4 = 16$ output terminals, one, and only one, of which is always connected to the input terminal (assuming negligible relay acting times).

From an inspection of the orderly pattern on which the tree network is constructed, convenient expressions for the number of network contacts can be immediately written. These expressions are

Possible relay combinations = number of output terminals = $2^n$.
Maximum number of transfer-contacts on one relay = $2^{(n-1)}$.
Total number of transfer-contacts in network = $2^n - 1$, where $n$ is the total number of relays.

A somewhat more uniform distribution of contact load on the circuit relays may be obtained by manipulating portions of the network. However, the total number of transfer-contacts cannot be reduced below $(2^n - 1)$, and any manipulations involving the relay originally carrying the single transfer-contact will, in general, increase the total number of contacts. A tree network need not be fully developed; that is, there may not be a corresponding output terminal for each possible combination of operated relays. This partially developed tree can also be manipulated to equalize contact load.

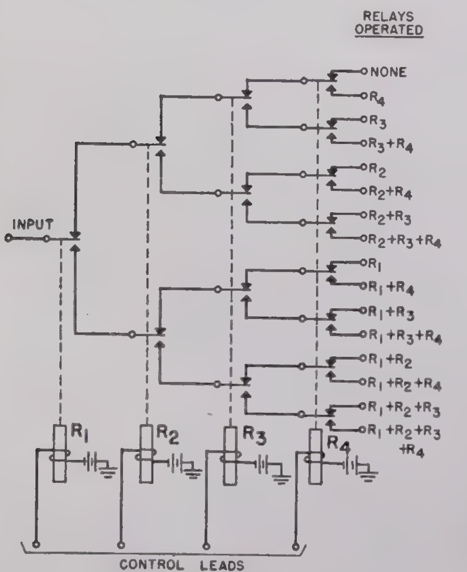


**Figure 1. A fully developed 4-relay "tree" circuit having 16 output terminals, one of which is always connected to the input terminal**

A symmetric relay-contact network is one in which the conditions for closing a particular input-to-output path are given in terms of the number of relays operated and released. For example, a network which is closed when any three, and only three, out of five relays are operated is a symmetric network. Chains and parallel groups of make- and break-contacts are elementary forms of symmetric networks since they can indicate conditions of all relays operated or released, or one or more relays operated or released.

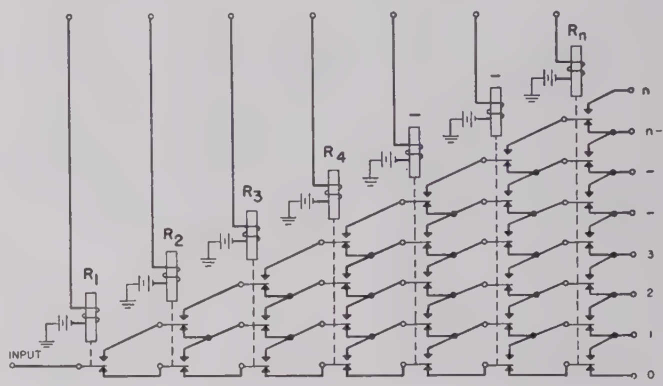


**Figure 2. Schematic diagram of general symmetric circuit**

A network for any symmetric circuit may be constructed of series and parallel elements. However, a general lattice configuration, similar to that of Figure 2, is more economical of contacts. This network has a single input point which may be connected to one of the several output terminals depending upon the number of operated relays. Inspection shows that, under no combination of relays operated, can more than one input-output path be closed.

To satisfy given requirements, this basic lattice form may be reduced to a network with a single output terminal by eliminating all undesired terminals and network paths. Expressions may be derived for this reduced form, as well as for the general lattice network, relating the total number of network relay-contacts to the number of relays in the circuit together with the conditions for network closure. Also, given relays with definite maximum contact loads, the maximum dimensions of all possible single-output symmetric networks can be determined.

Digest of paper 49-147, "Relay 'Trees' and Symmetric Circuits," recommended by the AIEE Communication Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# The ECPD Accrediting Program

DONALD B. PRENTICE

**The Engineers' Council for Professional Development program for the accrediting of engineering schools has resulted in a list of approved curricula which has proved of great value to secondary schools and to prospective students. The program, now 16 years old, covers to date the appraisal of some 700 curricula in 145 schools throughout the United States.**

AN IMPORTANT REASON for the establishment of the Engineers' Council for Professional Development in 1932 was the chaos that threatened in the possible accrediting of engineering schools by 48 or 49 different political agencies as the practice of licensing engineers spread from state to state and the District of Columbia. Every registration law for professional engineers had, and since 1932 has, recognized successful academic training as of more significance than apprenticeship and such recognition implies the designation of acceptable academic institutions whose degrees carry important academic weight.

Before 1932 we had lists of engineering schools approved by the University of the State of New York, by the Association of American Universities, by the regional accrediting agencies such as the North Central Association, and by the state departments of education. But we had no national accrediting of engineering schools by engineers or engineering associations. There was nothing similar to the approved list of the American Medical Association or the American Bar Association. The Society for the Promotion of Engineering Education might have undertaken the accrediting task, but although the matter had been frequently discussed, no action had been taken. And accrediting of teaching by teachers would not have carried as much weight as the method to be adopted through the Engineers' Council for Professional Development.

The Engineers' Council for Professional Development was formed for "the enhancement of the professional status of the engineer. To this end it aims to co-ordinate and promote efforts and aspirations directed toward higher professional standards of education, . . . ." Under "Program" the ECPD charter proposed, "(*b*). To formulate criteria for colleges of engineering which will insure to their graduates a sound educational foundation for the practice of engineering." Four standing committees are established by ECPD to carry out its aims and one of these, the Committee on Engineering Schools, "shall report to ECPD means for bringing about co-operation between the engineering profession and the engineering schools. As an immediate step the committee shall report to the Council criteria for colleges of engineering which will insure to their graduates a sound educational foundation for the practice of engineering." Dr. Karl T. Compton accepted the first chairmanship of the Committee on Engineering Schools and six engineers and educators served with him. The ECPD accrediting movement owes much of its success to the caliber of the men who formulated its objectives and methods and inaugurated the plan. From the very beginning the accrediting was welcomed by the engineering school administrative officers and faculty. There has been little adverse criticism of the results and in only one instance has the ECPD list failed of universal acceptance. In this single case the secondary accrediting agency later reversed its ruling and accepted the ECPD decision.

Full text of a conference paper presented during the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949.

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## BASIS FOR ACCREDITING COLLEGES

The committee under Dr. Compton's guidance prepared a "Basis for Accrediting Colleges" which was approved by the Council in October 1933. In the past 16 years of trial the basic plan has not been changed and the resulting list of approved curricula has been accepted by the national societies, the state boards of engineering examiners, several bureaus of the United States Government, and the engineering colleges themselves. The list is of inestimable value to secondary schools and to prospective engineering students.

Some of the basic principles adopted for accrediting are these:

1. Recognition of curricula rather than of institutions.
2. Consideration of undergraduate curricula only. (An ECPD subcommittee for accrediting graduate work is now studying that problem.)
3. Inspection of curricula only on invitation from the institution.
4. Avoidance of rigid standards; to prevent standardization and to encourage experimentation.
5. Accrediting only after inspection by competent examiners who will consider qualitative as well as quantitative factors.
6. Review of examiners' reports and recommendations by the inspection committee, the regional committee, the national committee, and finally by the Council itself.
7. Publication of list of approved curricula, all on same basis, with no reference to other unapproved curricula.

It should be noted that this list when approved by ECPD carries the endorsement of the founder societies, the American Institute of Chemical Engineers, the American Society for Engineering Education, and the National Council of State Boards of Engineering Examiners and therefore may

fairly be said to have the support and authority of the engineering profession.

The immense amount of work involved in the appraisal of some 700 curricula in 145 engineering schools throughout the United States could not possibly have been accomplished by the 7-man national committee. The country was therefore divided into seven regions, a member of the national committee made chairmen of each region, and regional inspection committees appointed. The constituent organizations of ECPD were invited to nominate competent representatives and the inspectors were chosen from these lists. It was inevitable that many regional inspectors should be faculty members, but from the beginning professional engineers were invited to join and now nearly 50 engineers from industry are participating in the accrediting program. Many of the college professors are consulting engineers as well and therefore represent an industrial point of view. At any rate, the accredited list has never been dismissed as "academic."

Although the Committee on Engineering Schools has consistently avoided regimentation, the plan of organization provides a reasonable and desirable degree of uniformity of treatment. There is no comparative approval; curricula are not rated A, B, C, and so forth, therefore friction and jealousy have been avoided, or at least kept to a very low minimum. Everyone knows that some accredited curricula are superior to others; but everyone knows, also, that any accredited curriculum provides the necessary and accepted minimum of training, facilities, and standards for the practice of engineering as a profession. Education beyond the minimum at some institutions is indicated by the records of alumni, college reputations with industry, and success in placing graduates.

The Committee on Engineering Schools has no required number of books in the engineering library, no fixed student–faculty ratio, no doctor's degree percentage for staff, and no minimum expenditure per student. In general the committee deliberately substitutes subjective judgment for elaborate statistics, personal estimates of quality of student work for square feet of laboratory space. As a result of the committee's examinations, about 75 per cent of engineering college curricula which have been inspected have finally been approved, about 12 per cent have been provisionally approved, and about 13 per cent have been turned down. More than 20 degree-granting colleges have never asked for inspection. If these engineering schools are considered to be self-evaluated below the recognized minimum for official approval then perhaps we can say that 65 per cent, or two-thirds, of the engineering curricula of the United States have been fully accredited.

## RATING OF TECHNICAL INSTITUTES

In recent years the accrediting program has been extended to technical institutes, through a subcommittee under the chairmanship of Dean H. P. Hammond. In many respects appraisal of programs of the technical institute type presents more difficulties than the rating of the 4-year degree curricula. In so far as feasible the subcommittee has followed the same procedure which has been found so satisfactory for colleges.

The technical institute field includes non-degree-granting institutions offering courses of one year or more beyond secondary school graduation. Such programs vary widely and will be found in the well-known technical institutes such as Wentworth, in university-sponsored institutes, in correspondence schools, in university extension courses, in Young Men's Christian Association and other evening schools, in proprietary schools, in junior colleges, and in industrial institutes such as the General Motors Corporation. It is hoped that official recognition by ECPD of sound training offered in schools of this type will have a desirable reaction upon prospective engineering students and will serve to increase the enrollment in preparation for service at a level of great usefulness to the engineering profession.

The work of the Committee on Engineering Schools has undoubtedly had an important influence on engineering education without standardizing it. The dean of a school whose program is antiquated, whose staff is underpaid, or whose equipment is inadequate, finds the report of an ECPD inspection committee an effective weapon. It carries weight with trustees, alumni, and faculty. In the past decade and a half immeasurable, but real, progress and modernization can be attributed to administrative pressure supported by recommendations of impartial examiners. From the very first it has been the policy of the Committee on Engineering Schools and its regional representatives to refrain from making any voluntary criticism and suggestion, but a college officer can secure friendly and confidential recommendations from the committee on request.

Service on the Committee on Engineering Schools was formerly limited to two terms of three years each, now to a total of five years. Personnel changes gradually but steadily so that there can be no just accusations of vested interests or clique control. As a matter of fact, I am certain no one has even intimated seriously any partiality. It has been necessary several times to issue stern warnings and even take action against undesirable political control of colleges, and this has had wholesome results, generally. On the other hand, the committee has repeatedly refused to interfere on behalf of some disgruntled student or teacher, believing that this is not its function unless standards are affected. The committee has consistently advised against the multiplication of curricula, but has never refused to inspect a specialized program when requested. Finally, the committee's freedom from specific requirements has made it possible to support cordially the ASEE recommendations for liberalizing engineering curricula by expanding the humanistic courses.

The work of the Committee on Engineering Schools of the ECPD is an excellent example of co-operative volunteer service for the good of the profession. The service will not be limited to accrediting, which was the committee's first and major task. Testing programs, student and faculty exchanges, co-operation with secondary schools for admission and with industry for placement, encouragement of graduate study, and many other activities may be included in the committee's program "toward higher professional standards of education."

# Carrier-Current Losses on 132-Kv Line

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THE Commonwealth Edison Company of Chicago and the Public Service Company of Northern Illinois have an interconnecting 132-kv power line over which a reliable carrier transmission channel is desirable.

The carrier channel difficulties arise chiefly from the 5.8 miles of 600,000-circular-mil paper-insulated oil-filled lead-covered cable extending out from Northwest Station. This length of cable would not be particularly difficult were it not for the fact that it is equipped with sheath bonding transformers which are used to reduce circulating currents in the sheaths. This avoids decrease in cable load capacity. However, the sheath bonding transformers present a very high loss return path to carrier-frequency currents. The overhead section of the line is 31 miles in length.

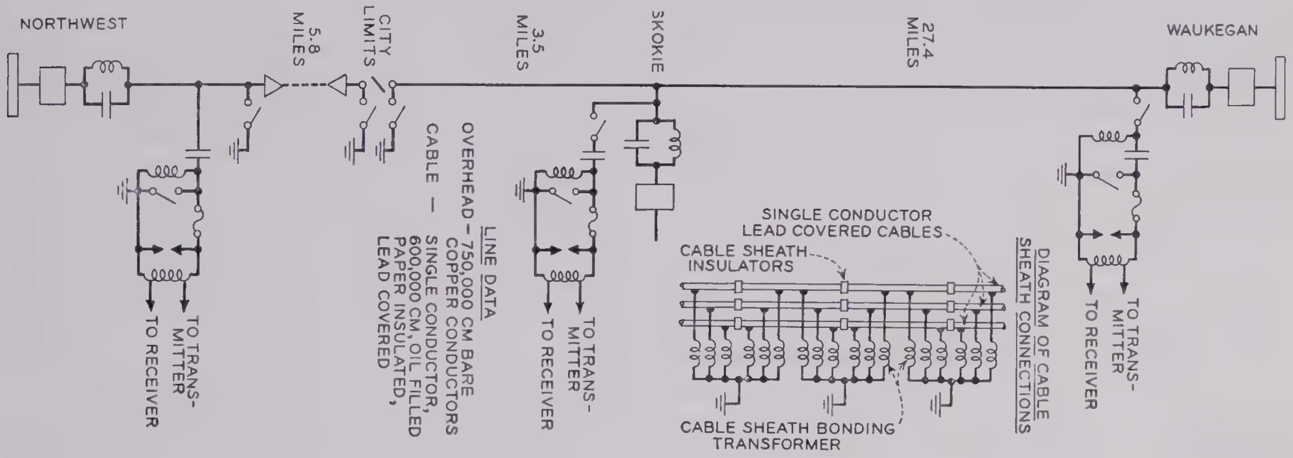


**Figure 1. One-line diagram of underground-cable overhead-conductor 132-kv line and diagram of cable sheath connections**

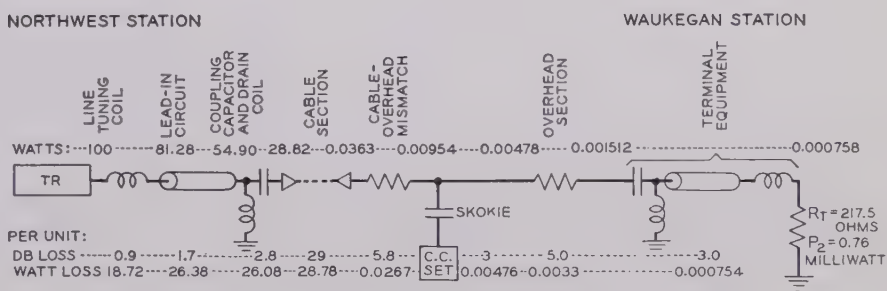


**Figure 2. Summary of losses at 75 kc**

Adding to the carrier problems are the increased terminal equipment losses at Northwest Station. These losses are greater than for an overhead line terminal, because of the fact that the carrier energy is fed into the low-impedance cable. The test results at Northwest Station show that 71 per cent of the available carrier energy at 75 kc is lost in the terminal equipment before reaching the 132-kv cable.

Other factors that contribute to the carrier transmission losses are: the cable-overhead conductor mismatch at the Chicago city limits (see Figure 1); the line tap at Skokie Substation; the normal overhead conductor attenuation; and the carrier terminal equipment loss at Station *6* in Waukegan. Losses and changes in attenuation also result from two other 132-kv lines that parallel the overhead section; line noise is increased by a nearby electric railway.

The carrier losses were measured in each component of the circuit. This was done to simplify the measurement techniques and also to determine what loss each component was contributing to the total. Resistance and capacitance substitution methods were used. Measurements were made at 50, 75, 100, and 150 kc.

Signal-plus-noise and noise measurements were made at Northwest Station, Skokie Substation, and Waukegan Station, using a standard noise meter and a specially designed converter unit to lower the frequency range of the noise meter to the 50–150-kc carrier band.

The following signal-to-noise ratios were obtained on a clear dry day at 75 kc: Northwest—314 to 1; Skokie—105 to 1; and Waukegan—74 to 1. The noise power of Waukegan was also measured and found to be 0.065 microwatt in the 217.5-ohm terminal resistance, $R_T$ (Figure 2).

Digest of paper **49-150**, "Loss Measurements Made on Underground-Cable Overhead-Conductor Transmission Line at Carrier Current Frequencies," recommended by the AIEE Carrier Current Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# The Binary Quantizer

KAY HOWARD BARNEY

**The binary quantizer is a new device for translating a time-varying voltage into a binary number. Although primarily designed for computing work, this apparatus may find use where quantization of a continuously varying function is desired, as in pulse code modulators, automatic metering devices, and recording machines employing typed or printed numbers.**

THE STUDY of servomechanisms, power systems, and similar devices has been greatly aided in recent years by the development of analogue computers. Many problems in the construction of analogue computers have not been completely solved. Among these is the problem of a multiplying circuit in which both the multiplier and the multiplicand are continuously varying quantities. A number of electronic and electromechanical circuits have been proposed for this job. However, a new approach to this problem is to translate, or quantize, the physical quantities in the analogue computer into numbers, multiply them together in a high-speed digital multiplier, and retranslate the product into the analogue system. The apparatus to be described in this article presents a means of translating the time-varying voltages or currents in an analogue computer into discrete binary numbers, the size of each being directly proportional to the instantaneous value of the quantity being measured, thus making possible digital techniques in an analogue computer. A system using the binary quantizer is shown in Figure 1.

## THE BINARY QUANTIZER

There appear to be two general methods for using a binary counter to translate the instantaneous amplitude of a time-varying signal into a binary number. One of these methods, developed by the Bell Telephone Laboratories,[1] is to use a binary counter consisting of several cascaded flip-flop circuits that counts up from zero for a period of time that is proportional to the instantaneous amplitude of the input signal each time a sample of the input signal is taken. The counter is then reset to zero and another sample of the input signal is taken.

The second method is employed by the quantizer described in this article which uses a binary counting circuit consisting of four cascaded flip-flop* circuits in which the count may be made to progress either forward or backward. To the counter is attached a voltage feed-back circuit which produces a voltage proportional to the count standing on the counter at any instant of time. This feed-back signal is used to oppose the original input signal, the one to be translated to binary digits. When a difference exists between the input and the feed-back voltages, the counter is operated in a direction controlled by the sign of this difference or error voltage. The counter will then count until no difference appears between the input and feed-back voltages. At this time the counting stops, and the counter awaits any new change in the input signal.

*The Principle of Forward and Backward Counting.* The usual binary counter consists essentially of the circuit of Figure 2. This shows a set of flip-flop circuits connected so that the plate of one triode of the first flip-flop stage is connected to the input circuit of the following flip-flop stage, and so on. The flip-flop itself is shown as two boxes each of which represents one of the triodes. The numerical value of the count is indicated by the neon bulbs, the digit, 1, being registered when the lamp is "on" and the digit, 0, when the lamp is "off." Each flip-flop bears the coefficient, *1*, *2*, *4*, or *8*, as indicated in the diagram. Thus, if the lamps on stages number *2* and number *4* were "on," a total of six pulses would be registered. To further understand the operation of this counter, it must be kept in mind that the flip-flops in this circuit change position, that is, from one stable state to the other, upon the receipt of negative pulses only.

The operation of this chain may be explained by the following example. Consider the count standing initially at zero, that is, all neon lamps "off." Upon the receipt of the first pulse, the first flip-flop changes to its other stable state, the plate connected to the neon bulb goes positive, and the lamp lights, indicating the number, 0001 = 1 This also sends a positive pulse to stage number *2*, but since only negative pulses can change its position, nothing further happens. The next input pulse again changes the position of stage number *1* which, as the lamp is extinguished, sends a negative pulse to stage number *2* causing it to change to its other stable position lighting its lamp indicating the number 0010 = 2. Since stage number *2* emits a positive pulse, stage number *4* is unaffected and again the counter stands at rest. The next input pulse again changes stage number *1* so that its lamp again lights and it emits a positive

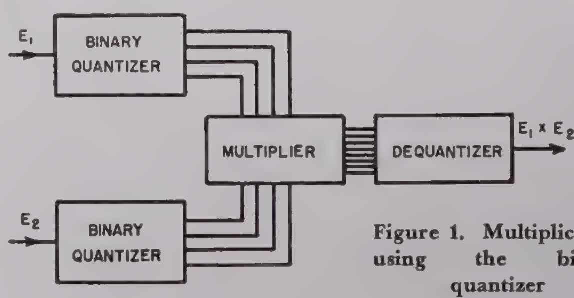



**Figure 1. Multiplication using the binary quantizer**

A thesis prepared for a master's degree at Northwestern University, Evanston, Ill.

* A circuit consisting of two interconnected triode units having two stable states. Either the first triode is conducting and the other is not, or the first is nonconducting and the second conducts.

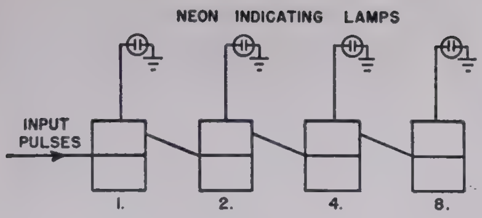



**Figure 2. Block diagram of the usual binary counter connected to count forward**

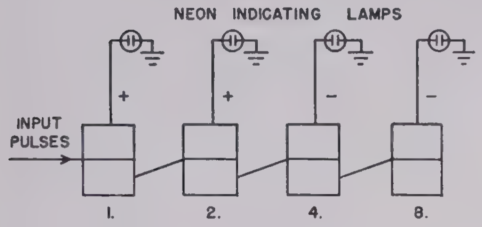



**Figure 3. Binary counter connected to count backward (polarities indicate the number three)**

pulse which does not affect stage number *2*. The count now stands at 0011 = 3. In this manner, the circuit counts the input pulses in the forward direction until the number 1111 = 15 is reached. The next pulse will reset the counter to 0000 and the count will again progress forward.

The circuit of Figure 3 is identical with that of Figure 1 except that the stage following each flip-flop is triggered by the output of the plate to which there is no neon bulb attached. As before, only negative pulses will trigger the flip-flop.

Assume that the count stands at 0011 = 3, that is, the bulbs of stages number *1* and number *2* are lit (the polarities of the flip-flops are shown for this condition). The first input pulse received changes the position of stage number *1*, but since negative pulses alone affect the following stage, the lamp is merely extinquished on stage number *1*, and the count stands at 0010 = 2. The next input pulse lights the lamp of stage number *1* and again drives the opposite plate of this flip-flop from positive to negative, causing a negative pulse which triggers the stage number *2* and extinguishes its lamp. The count is now at 0001 = 1. The next input pulse changes stage number *1* again and extinguishes its lamp. Now the count is 0000. The next pulse will place the counter at 1111, and the counter will continue to count down from there. Thus it can be seen that the direction of the count of the binary stages may be reversed by switching all the interstage connections.

*The Operation of the Quantizer.* The application of this principle is shown in the block diagram of the quantizer, Figure 4. The error signal, or the difference between the input signal and the voltage representing the count standing on the counter, opens the forward or the backward gates, depending on the sign of the error as it is amplified through the error and gating amplifier. The counter will now respond to pulses from the oscillator which operates continuously.

A voltage feed-back circuit is attached to each stage. These are adjusted so that one unit of voltage is fed back from stage number *1* when it indicates the digit, 1, and no voltage is fed back when it indicates the digit, 0. Likewise, stage number *2* will feed back two units of voltage, stage number *4*, four units, and stage number *8*, eight units when they stand at 1, and no voltage when they stand at 0. The sum of the voltages fed back at any instant of time is compared to the input signal through a feed-back network.

The numerical output of the quantizer appears as a combination of voltages on the wires *1*, *2*, *4*, and *8*, a ground indicating the digit, 1, and −25 volts indicating the digit, 0.

In the actual circuit the voltage feedback unit is a pentagrid converter-type tube which is cut off when the binary stage stands at 0, and which conducts a current proportional to the binary value of the stage to which it is connected when that stage stands at 1. When conducting, the feed-back circuit of stage number *1* will pass one unit of current, that of stage number *2*, two units of current, that of stage number *4*, four units, and so on. The plate currents of all the feed-back tubes are caused to flow through a common plate-load resistor. The voltage drop across this resistor at any time will be proportional to the count standing on the counter at that time. It is this voltage that is compared with the input signal. If a positive error appears, the forward bus goes to ground potential permitting operation of the forward gates which allow the counter to count forward. Likewise, a negative error causes the backward bus to go to ground potential, allowing the count to progress backwards. Thus, as the block diagram indicates, the counter counts only when the input signal changes, and the numbers "follow" the instantaneous amplitude of the input signal.

DISCUSSION OF THE CIRCUITS

As the schematic diagram, Figure 5, indicates, the actual circuits used in the binary quantizer are quite conventional. (The schematic diagram shows all the circuits including the first binary counting stage. The following

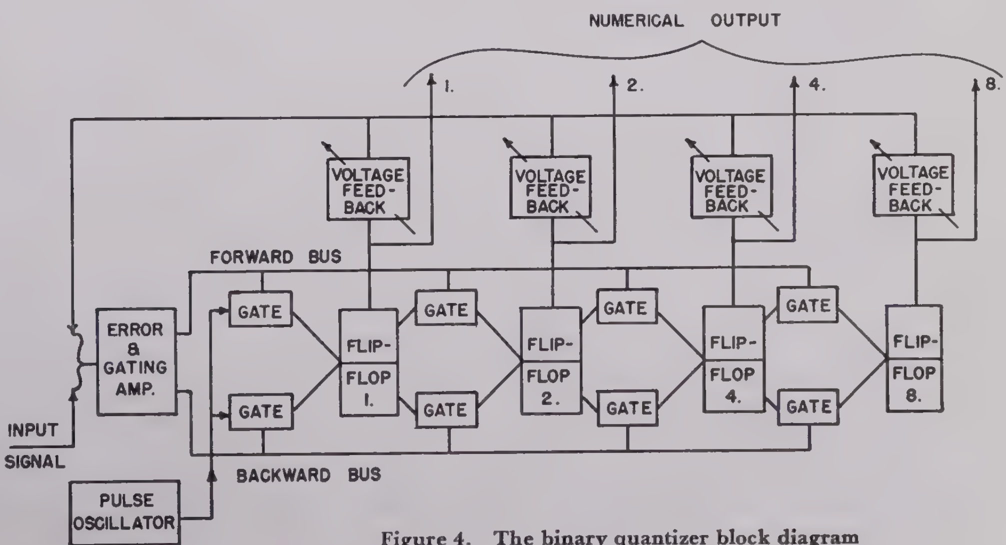



**Figure 4. The binary quantizer block diagram**

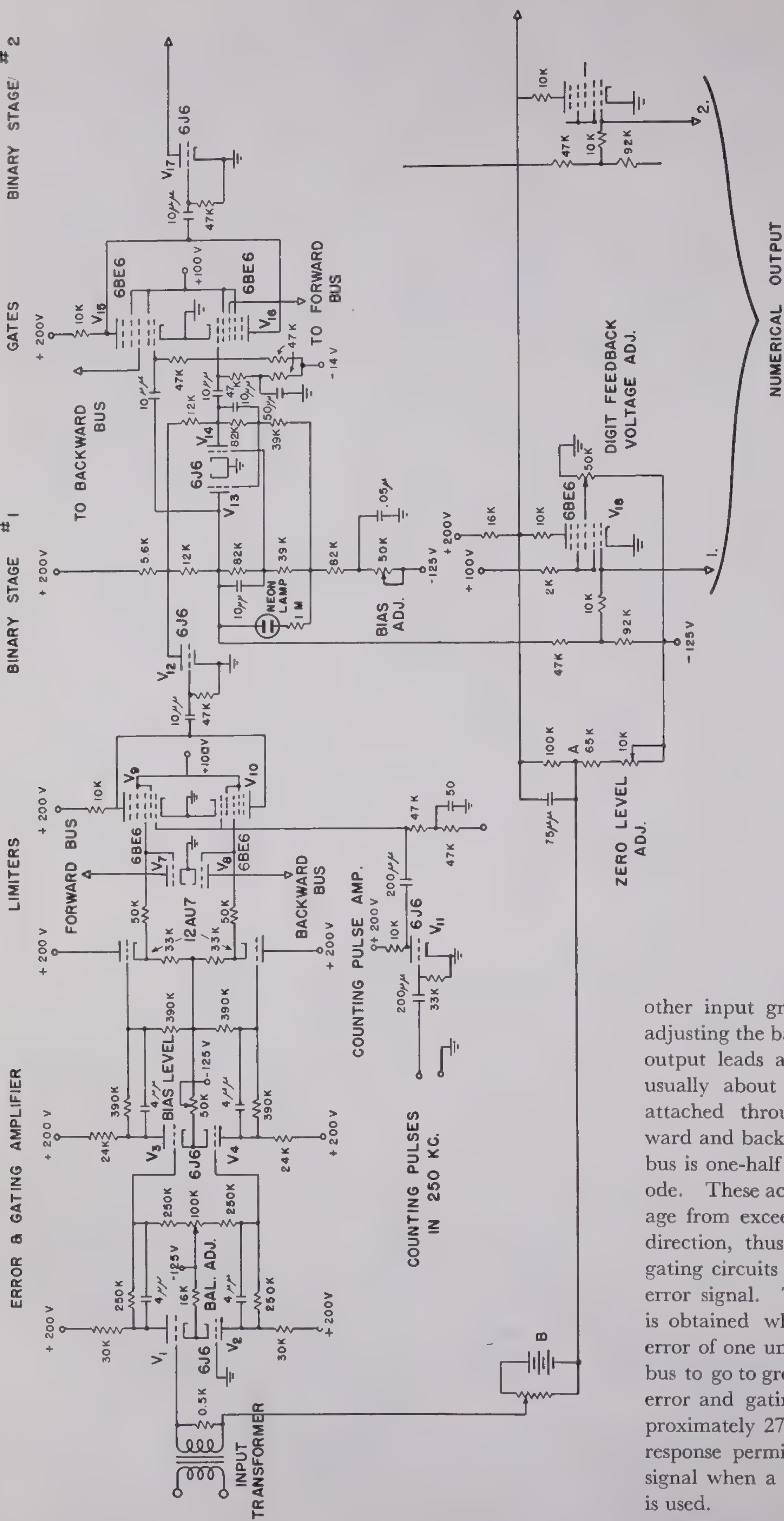



**Figure 5. The binary quantizer schematic**

binary stages, although not shown in this diagram are identical to the first one in all respects.) The circuits are constructed entirely for use with miniature tubes, three types being employed, *6J6* (duo-triode), *6BE6* (pentagrid converter), and the *12AU7* (duo-triode). Three voltage sources are required, 200 volts, 100 volts, and −125 volts, from which a fourth voltage of −14 volts is obtained by means of a bleeder circuit. The filament supply is the usual 6.3 volts, alternating current. All power supplies save that of the filament must be well regulated. The 200-volt and the 100-volt supplies have current drains of about 75 milliamperes maximum. The 125-volt source must supply about 50 milliamperes.

The error and gating amplifier is an ordinary direct-coupled push-pull amplifier using two *6J6* tubes as amplifiers and a *12AU7* tube for a cathode follower output. One of the grids of the input tube to this amplifier is grounded so that the error signal is measured with respect to ground.

This amplifier is adjusted by also grounding the other input grid, simulating zero error, and then adjusting the balancing and level controls until both output leads are at the same negative potential, usually about −25 volts. These output leads are attached through 50,000-ohm resistors to the forward and backward busses. Also attached to each bus is one-half of a *12AU7* tube connected as a diode. These act as limiters to prevent the bus voltage from exceeding ground potential in a positive direction, thus ensuring proper operation of the gating circuits regardless of the magnitude of the error signal. The exact setting of the level control is obtained when the feed-back voltage from an error of one unit causes the forward or backward bus to go to ground potential. The response of the error and gating amplifier is flat from zero to approximately 270 kc per second. This frequency response permits satisfactory detection of the error signal when a counting rate of 250 kc per second is used.

The output of a standard radio-frequency generator is amplified by the counting pulse amplifier. This

signal is sufficient to overdrive the input gate tubes. The input gating circuit, identical to the rest of the gating circuits, consists of *6BE6* pentagrid converter tubes. To the first grid is fed the output of the counting pulse amplifier. This grid is biased at cutoff (−14 volts) so that only positive signals will be amplified. The third grid is attached to the forward or backward bus which will both be at a potential of −25 volts when there is no error signal. With the appearance of an error, the forward or the backward bus will go to ground potential permitting the operation of all the forward or backward gates.

With the counter in operation the output of the input gate consists of negative pulses which are amplified and inverted by the *6J6* trigger tube preceding the first flip-flop. The output of the trigger tube appears as positive pulses across the 5,600-ohm resistor.

The flip-flop circuits (all identical, each with its own trigger tube) consist of two triode halves of a *6J6* tube connected in a standard Eccles-Jordan circuit, that is, the plate of one triode is directly coupled by means of a voltage divider to the grid of the other. This circuit will have two stable conditions: triode *a* conducting and triode *b* cutoff; or triode *a* cutoff and triode *b* conducting. A positive pulse appearing across the 5,600-ohm resistor will be coupled to the grids of both triodes. This pulse will have little effect on the grid of the conducting triode. On the other hand, this positive pulse will bring the cutoff triode into conduction. The rise of voltage on the grid of the former cutoff tube is amplified and inverted and coupled to the other conducting triode driving it rapidly into cutoff. When this has occurred, the circuit will remain at rest with the original cutoff triode conducting and the other cutoff. These conditions will be reversed again when another positive pulse from the trigger tube is received across the 5,600-ohm resistor. When the counter is in continuous operation, the voltage wave form on each of the plates of the triodes comprising the flip-flop will be approximately square. This square wave is differentiated by the coupling resistor and capacitor combination (47,000 ohms and 10 micromicrofarads) and the resulting pips are applied to the succeeding gate circuit. One or the other of the gating tubes, depending upon the direction of the count will amplify the positive portion of this signal which is again differentiated and applied to the trigger tube of flip-flop number *2*.

As the section on "Principle of Forward and Backward Counting" indicated, the flip-flop circuits (including the trigger tube) must be triggered by a negative pulse only. If the count is to be in a forward direction, this negative pulse must appear at the trigger tube of the following flip-flop at the same time that the neon bulb attached to the first flip-flop is extinguished. Since the gating circuits invert the signal and operate on positive signals only, to count forward, the plate of the triode to which there is no neon bulb attached must be connected through the gating circuits to the trigger tube of the following flip-flop. Assume now that the neon bulb of stage number *1* is lit. When stage number *1* receives a pulse, the plate attached to the neon bulb goes negative. At the same time the other plate goes positive. It is this positive pulse that is amplified and inverted by the gate attached to the forward bus giving the required negative input pulse to the next stage. Upon receiving another pulse, stage number *1* again changes to its other stable state; its neon bulb lights meaning that the plate attached to the forward gate has gone negative. As negative pulses are not amplified by the gating tubes, there will be no signal applied to the trigger tube of stage number *2*. This fulfills the conditions for forward counting. Backward counting also may be demonstrated in a like manner.

Connected to the plate of the triode to which a neon bulb is attached is a voltage divider consisting of a 47,000-ohm resistor in series with a 92,000-ohm resistor whose other end is connected to − 125 volts. This combination of resistors is such that when the neon bulb is "off" the feed-back amplifier is cutoff. When the neon bulb is "on," the plate current of the feed-back amplifier is controlled by the potential on the third grid of the *6BE6* tube. The screen current is limited to a safe value by the 2,000-ohm resistor. The plate currents of all the feed-back amplifiers flow through the 16,000-ohm resistor. The voltage across this 16,000-ohm resistor is directly coupled by the voltage divider, consisting of the 100,000-ohm, 65,000-ohm, and 10,000-ohm resistors, to the input transformer and thence to the input of the error and gating amplifier. Any change in input signal is thus added in series with the feed-back voltage.

When the count stands at zero, the zero level adjust is adjusted so that the junction of the 100,000-ohm and the 65,000-ohm resistors (junction *A*) is at ground potential. Then, with the neon bulb of stage number *1* "on," the digit feed-back adjust is adjusted to give −2 volts at junction *A*. In a like manner, the digit feed-back adjust of stage number *2* is adjusted to give −4 volts at junction *A* when neon bulb number *2* is "on" and the rest are "off." Similarly, stage number *4* is adjusted to give −8 volts and stage number *8* to give −16 volts. The amplifying circuits have been found to work the best with these potentials.

To allow quantization of signals having both positive and negative values the quantizer is "biased" to the number seven by the battery, *B*. Then signals applied through the input transformer will be quantized using the numbers from zero to seven for the negative portion of the signal and the numbers 8 to 15 for the positive portion of the signal. A 75-micromicrofarad capacitor is connected from junction *A* across the 100,000-ohm resistor to compensate for the shunt capacities to ground of the transformer windings. The neon bulbs have been used in the counter circuits to aid the adjustment of the counter and for demonstration purposes only as the useful numerical output will consist of the combination of voltages appearing at the grids of each of the feed-back amplifier tubes.

As any drift in the circuit parameters of the components forming the feed-back circuit will be manifested in the digital output as discrete steps, small changes will not be registered. During the warm-up period the zero level adjust must occasionally be adjusted to keep junction *A* at zero potential when the count stands at zero. Any change in the feed-back amplifier tubes will also cause numerical inaccuracies. However, although no long run

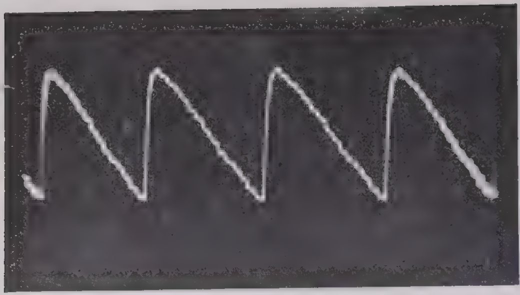
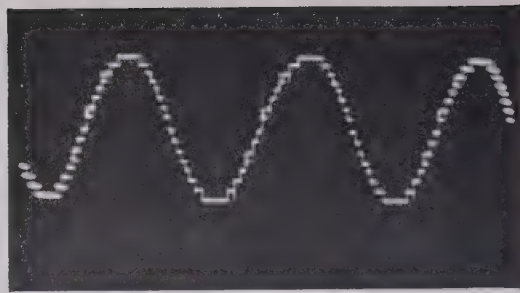


Figure 6 (left). Feedback voltage when counter runs freely as an open loop circuit

Figure 7 (right). Feedback voltage when a sinusoidal voltage is quantized



tests have been performed on the binary quantizer as constructed in the laboratory, satisfactory operation at various intervals over a period of a few weeks has been obtained without any adjustment except for that of the zero level adjust.

The stability of the quantizer operating as a closed loop system may be analyzed on the basis of two considerations. First, the amplifiers and the feed-back system must be capable of determining within the period of time between pulses from the oscillator that an error has been corrected. In the quantizer described it was found that a flat response from zero to approximately 270 kc per second was satisfactory when a counting rate of 250 kc per second is used.

The second consideration involves the operation of the quantizer when the instantaneous amplitude of the input signal is not equal to an integral number of feed-back voltage units. At first glance it might appear that a signal amplitude halfway between the amplitude of two possible levels of the feed-back voltage might cause the output of the counter to oscillate. However, because of the high gain of the error and gating amplifier and the fact that the counter operates only when the forward or the backward bus is within a volt of ground potential, there is a considerable dead zone between levels. This dead zone increases as the gain of the error and gating amplifier is increased providing that the bias level adjust of the error and gating amplifier is always adjusted so that an error of one unit causes the forward or backward bus to go exactly to ground level.

## WAVE FORMS

The operation of the binary quantizer is further illustrated by Figures 6, 7, and 8. These are pictures of the voltage appearing across the 16,000-ohm common plate-load resistor of the feed-back circuit. When the counter is allowed to run freely (as an open loop system), the wave form shown in Figure 6 will be produced across this resistor. This shows the counter operating at a rate of 250 kc per second. The height of each step is proportional to the count standing on the counter at that particular instant of time.

Figure 7 shows the voltage across this common plate-load resistor when the input circuits are all connected and a sine wave is introduced at the input of the binary quantizer. Note that the feed-back voltage is a quantized replica of the input. Each step indicates that the counter has remained at rest at a particular number until the error between the input signal and the feed-back voltage has exceeded a certain limit determined by the sensitivity of the error and gating amplifier. When this limit is exceeded, the count will be advanced by one pulse and the counter will again remain at rest until a large enough error appears. The numerical output appears as a combination of voltages of the leads labeled "numerical output" in Figures 4 and 5.

When excited by a square wave the binary quantizer will have the feed-back voltage wave form shown in Figure 8. This shows the counter counting up the sides of the square wave. At the top, the feed-back voltage equals the signal voltage and the counter remains at rest until another change in input voltage occurs.

## APPLICATIONS IN THE FIELD OF SERVOMECHANISMS

When it becomes understood that the counting circuits of the binary quantizer function only when there is a change in the instantaneous amplitude of the input signal, a novel application of this device presents itself. The entire apparatus may be used to function as a differentiator circuit by the addition of the circuit of Figure 11.

Whenever the machine is counting, positive pulses will appear at the plate of the trigger tube of the first binary stage. In addition to being fed to the first stage of the binary counter these pulses are also used to drive the grids of $V_1$ and $V_2$ (of Figure 11). If the counter is counting backward, $V_2$ will be gated by its connection to the regular backward bus, and its output consisting of

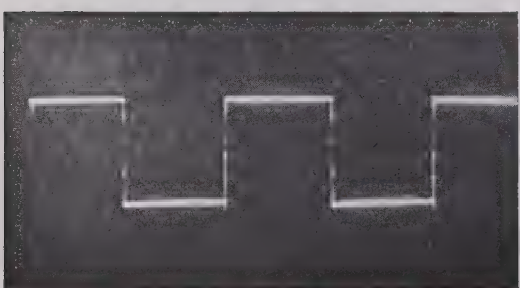
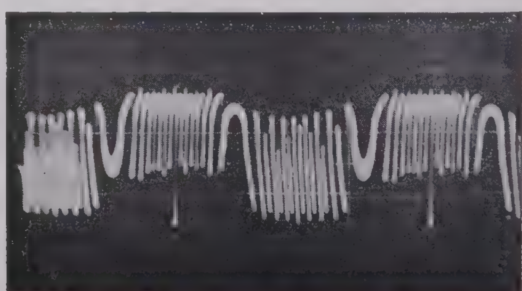


Figure 8 (left). Feedback voltage when a square-wave voltage is quantized

Figure 9 (right). Backward bus voltage when a sinusoidal voltage is quantized



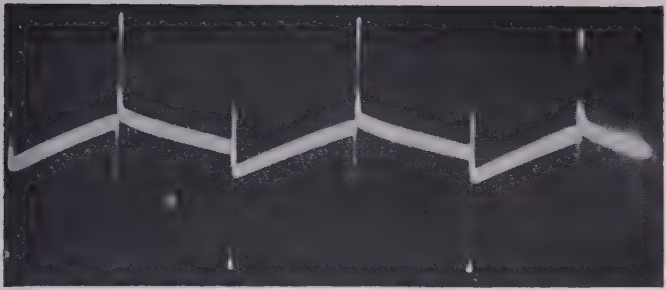


Figure 10. Backward bus voltage when a square-wave voltage is quantized

negative pulses of uniform height but spaced according to the derivative of the input signal will then appear across $R_6$. Since the forward bus is negative beyond cutoff at this time, there will be no output through $V_1$ and $V_3$. However, should the counter count forward, positive pulses will again appear on the grids of $V_1$ and $V_2$, but the forward bus will now gate $V_1$ whose negative output is inverted to give a positive set of time-spaced pulses across $R_6$ whose spacing and sign are determined by the derivative of the input signal as shown in Figure 12.

Integrated by a counting rate measuring circuit, these pulses will give a good approximation of the derivative of the input signal and may be amplified as desired.

Although this circuit has not been constructed, the derivative effect may be seen in Figures 9 and 10. These are the wave forms existing on the backward bus when a sine wave is quantized (Figure 9) and when a square wave is quantized (Figure 10). These show the pulses that appear each time the error is corrected by advancing the count by one pulse. Figure 10 actually shows in the vertical line a group of pulses placed very close together. In this illustration the horizontal line is widened somewhat due to small a-c pickup which was amplified by the directly coupled error and gating amplifier and appears as a wide line in the time exposure.

CONCLUSIONS

The binary quantizer described in this article utilizes two techniques: a binary counting circuit that counts either forward or backward; and a circuit that produces a

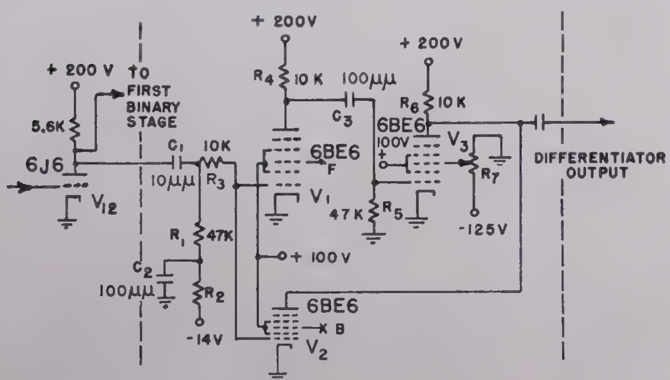
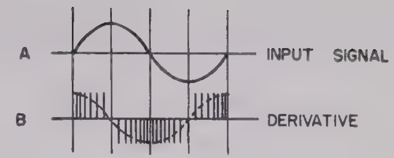



Figure 11. Differentiator circuit

Figure 12. Differentiator circuit output with sinusoidal input voltage




voltage proportional to the count standing on the counter at any instant of time. These two features are combined in an apparatus whose numerical output is available on the register of the machine at all times and may be directly coupled to the digital computer which will perform the operations on these numbers. Since counting occurs only when required by a change in the instantaneous value of the input signal, the output of the binary quantizer "follows" the input signal as it changes at intervals depending on the rate of change of the input signal, the upper limit being the period of the master oscillator, which is four microseconds in the design described. Furthermore, increased digital accuracy in the form of more binary stages will not change the sampling rate.

While the counting circuits of the binary quantizer will operate at counting rates well in excess of five megacycles per second, a counting rate of 250 kc per second was chosen to enable ordinary resistance–capacitance coupling circuits to be used throughout the feed-back circuits. This resulted in a great saving in the time required to construct the quantizer in the laboratory. If such devices as inductive compensators and crystal diode coupling circuits were incorporated, and a better placement of components were considered for the feed-back circuits (often impossible in the breadboard design), greatly increased counting rates could be used resulting in smaller sampling intervals.

The use of this quantizer with the advantages of the reversible counter and the feed-back circuit may aid in the development of new approaches in the fields of analogue-digital computing, and servomechanisms.

## Appendix. Distortion of a Quantized Signal

The number of binary digits carried by a quantizer will determine the maximum number of discrete levels into which the input signal may be quantized. The following table[2] gives the distortion of the fundamental when a sine wave is quantized into various numbers of levels.

| Number of Levels per Half Cycle | Per Cent |
|---|---|
| 5 | 8.16 |
| 10 | 4.09 |
| 20 | 2.04 |
| 50 | 0.81 |

Therefore, if the over-all accuracy of the analogue computer is between one and two per cent, a quantizer employing five binary digits (31 levels) would be satisfactory for use in this analogue computer.

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# 69-Kv Pipe-Type Cable Circuits

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FOUR 880-ampere 69-kv pipe-type circuits recently were installed by the Philadelphia Electric Company. Three use oil and the other uses gas as the pressure medium.

The 1,500,000-circular-mil conductor size for oil pipe-type circuits was estimated to have essentially the same copper temperature at 880 amperes as that for 1,500,000-circular-mil oil-filled cable in duct. The larger 2,000,000-circular-mil conductor for high-pressure gas-pipe cable was specified to gain an expected lower copper temperature rise of 48 degrees centigrade ultimate, as compared to 50 degrees centigrade for oil-filled cable and 52 degrees centigrade for the oil pipe-type cable. Excessive losses in two gas-pipe cable designs have increased their ultimate temperature rises from the expected 48 to 55 degrees centigrade and 58.5 degrees centigrade, respectively. All of these calculations assume the earth to have a resistivity of 80 thermal ohm-centimeters. A rather extensive program of tests begun in 1947 indicates that the average thermal resistivity of earth in Philadelphia is very nearly 75 thermal ohm-centimeters, with a range from 34 minimum to 114 maximum in the characteristic clay subsoil.

These particular pipe-type circuits were designed to operate under a load cycle which was recognized to place a severe limitation on load rating. It was expected that the thermal resistivity of the earth would exceed 80 thermal ohm-centimeters at some locations and in some seasons, as confirmed by subsequent tests. Therefore, the copper temperature in the design selected for the pipe-type cables was expected to exceed the normal operating limit of 75 degrees centigrade where such conditions prevail in small percentages of their length, but only if the operations at that particular season require the full load rating under an adverse load cycle.

The sturdy qualities of high-pressure oil-pipe systems suggest it may be practical to accept the possibility of occasionally operating such cables at normal copper temperatures ranging up to 100 degrees centigrade. The occasions would be infrequent. The sheath crack problem is not present. Slight additional restraint against the somewhat greater expansion forces is provided readily. The only effect can be some life loss in scattered locations along the circuit.

The oil-pipe cable and about half of the gas-pipe cable have 315 mils of insulation, mass-impregnated with mineral base oil having a viscosity of 2,500 to 3,000 Saybolt seconds at 100 degrees Fahrenheit. The remaining 2,000,000-circular-mil gas-pipe cable is mass-impregnated with a synthetic oil having a viscosity of 140,000 Saybolt seconds at 100 degrees Fahrenheit.

The gas-filled insulation was not expected to have the same rugged electrical qualities as high-pressure oil-filled cable insulation. From the operating point of view, however, there appears to be no reason to expect the 69-kv high-pressure gas-filled insulation to be any less satisfactory than oil-filled cable insulation, provided the inherent design limitations are observed.

All of the Philadelphia pipe-type circuits have a 7/16-inch wall of Somastic, Type II coating designed to maintain its integrity at temperatures up to 65 degrees centigrade, as needed for such construction. This coating is somewhat brittle at freezing temperatures; hence, the location and repair of defects commonly known as "holidays" can be simplified considerably by avoiding winter construction schedules where practical.

The manhole locations and related cable-pulling lengths for the approximately 20 miles of pipe-type cable circuits installed to date all had to be established before any cable had been installed. It has been found since that somewhat longer cable-pulling lengths are permissible. Using the percentage ratio of total cable cross section to internal area of the pipe as a measure of occupancy, the first two 1,500,000-circular-mil circuits occupied 41 per cent of their $6^1/_8$-inch-inside-diameter pipes, the third 1,500,000-circular-mil circuit occupied 45 per cent of its $5^7/_8$-inch-inside-diameter pipe, and the 2,000,000-circular-mil circuit occupied 48 per cent of its $6^1/_8$-inch-inside-diameter pipe. Forty per cent occupancy has been considered altogether reasonable, but the higher percentages required for the later installations were considerably beyond the limits of common practice. For instance, the circumscribing circle limit of three cables in a pipe, is 65 per cent occupancy in the foregoing reference scale. For bends, the pulling tension added is determined predominantly by the cable tension at the entrance to the bend, the arc length of the bend and its radius.

The $6^1/_8$-inch-inside-diameter pipe was considered practically ideal for 1,500,000-circular-mil cable in pulling lengths of 1,500 feet maximum, which experience has now shown can be increased substantially. For purposes of design, the maximum pulling tension is limited to the 10,000 pounds per square inch, nominal elastic limit of soft drawn copper conductor, assuming that one conductor may have to withstand one-half the total pulling tension.

In the oil-pipe circuits, there is a semistop joint at each cable joint, with by-pass piping and automatic valves designed to reduce materially the rate of oil supply to any section in which the oil pressure drops below 75 pounds per square inch. The system has appeared to work well when supplying oil demands from a pump at one end of a circuit if its length is about 4.5 miles with 18 semistop joints.

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Digest of paper **49-136**, "69-Kv Pipe-Type Cable Circuits in Philadelphia," recommended by the AIEE Insulated Conductors Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Bolometer Detection of Line Temperature Rise

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**An infrared-detecting bolometer, suitable for measuring the temperature rise of conductor joints and switch contacts while in service, has been developed by the research division of The Hydro-Electric Power Commission of Ontario, Canada, and has been used during the past year in the field with a great amount of success.**

THE LOCATION of high-resistance transmission line joints on circuits long in service has been an almost routine procedure of many utilities for some time past. Considerable effort has been expended by The Hydro-Electric Power Commission of Ontario in making such measurements. Many of the circuits, of aluminum cable steel-reinforced (ACSR) construction, are now over 25 years old. Bearing in mind the limited knowledge of techniques for joining aluminum conductors which existed at that time, it is not surprising that some conductor joints began failing after a useful life of 25 or 30 years. The seriousness of such failures regarding danger to life and interruption of service is apparent.

The greatest offender has been the screw-type compression joint used on the early 110-kv circuits. This joint had an aluminum compression sleeve made of two parts which threaded together. The screw portion in many cases was found to be the source of the high resistance. In some cases, this portion must have become almost an open circuit, whereupon the line current passed through the steel sleeve. The resulting temperature rise was sufficient to soften the steel until the joint pulled apart. In other instances the current distribution was found to be nonuniform, a few strands carrying most of the current.

About 1939, the failures had reached sufficient proportions to warrant a full-scale investigation. Joint testers were constructed using a Wheatstone bridge circuit, the joints being compared with an adjacent portion of the cable of equal length. This testing was carried out by means of lineman's trolleys, with the line out of service but otherwise normal. Many miles of line were examined in this manner from the years 1939 to 1941.

During the war, the development of infrared bolometers for heat detecting purposes progressed to a remarkable extent. The Germans had equipment of this nature which was capable of accurately tracking the course of a ship through the English Channel. The detectors, which were mounted on the Cliffs near Calais, France, picked up radiation from the ship's funnel.

The sensitivity of these devices, and their robustness was such that their application to the detection of overheated joints was considered practical. Thus, a device was developed in the research division of The Hydro-Electric Power Commission during 1947 and 1948, following the description of a somewhat similar device by C. D. Niven, National Research Council, Ottawa, Canada, in a private communication.

With the infrared detector, joint temperatures can be measured with the line in normal service by merely setting up the detector's tripod to one side of the line and sighting the bolometer on the joint. This procedure takes less than five minutes time.

During the past two months, more than 300 transmission line joints have been checked. Present performance is such that, depending on terrain, and so forth, 25 or 30 joints may be measured on good days on a double circuit line. The temperature can be measured to ±5 degrees centigrade providing the joint is more than 10 degrees centigrade above ambient. The approximate joint resistance can be calculated.

Application of the device to heavy-current switch contacts and miscellaneous clamps has also been made. Of the first 12 switch contacts measured, one was found which was dissipating almost 200 watts on the contacts.

The demands on the apparatus for all this work are such that a 2-man crew is presently working full time with the apparatus.

## DESCRIPTION OF INSTRUMENT

The infrared detector or bolometer is shown on its tripod in Figure 1. It consists of two parts—a parabolic mirror which collects the heat radiation from the joint, and a heat sensitive element mounted at the focus of the mirror. The sensitive element is a resistor with a high negative temperature coefficient. The change in resistance is a measure of the heat radiation falling on the mirror.

The parabolic mirror is made of glass, eight inches in diameter with a 6-inch focal length. It is precision ground and has an aluminized front surface. The long wave infrared radiations given off by the joint do not pass through glass so that the polished aluminum must be on the front of the mirror.

The sensitive element is a Western Electric thermistor bolometer, type *V651*,[1] developed by the Bell Telephone Laboratories. The active area (termed a "flake" by the manufacturer) is 2 millimeters by 0.2 millimeter, and about 10 microns thick. Thermistors are thermal resistors with a

Full text of paper **49-9**, "Detection of Overheated Transmission Line Joints by Means of a Bolometer," recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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temperature coefficient of about −4 per cent per degree centigrade. The element is enclosed with a compensating element in a small housing with a rock-salt window through which the radiations pass without absorption.

The circuit is so arranged that the voltage across the thermistor is proportional to the resistance, and the sensitivity is given as 250 microvolts per microwatt incident radiation.

A front end view of the bolometer, showing general construction, is given in Figure 2.

In order to facilitate the amplification of the minute voltages set up by the bolometer, the incoming radiation is interrupted at a regular rate (15 cycles per second) by means of a rotating semicircular sector disk mounted in front of the element. The thermistor element is heated cyclicly at the disk frequency and cools by virtue of its small size each time the radiation is interrupted.

Figure 1. Bolometer in use

The disk is driven with an elastic band and pulley arrangement from a small motor mounted to one side of the mirror axis. The output of the bolometer is thus a 15-cycle square wave which can be amplified in a stable manner. The driving motor is a reed-synchronous type having a speed variation of less than ±0.3 cycle per second. It is driven from a 6-volt motorcycle battery. The amplifier is tuned to the disk frequency so that it is insensitive to extraneous voltages.

The box containing the amplifier and batteries is shown beside the tripod in Figure 1.

The use of a rotating sector disk has a further major advantage in that the chopping disk can be made of material (glass, mica, quartz) which is opaque to long wave radiations but passes the visible and near infrared waves. The latter are thus not modulated and produce only a d-c component (steady heating) which is not amplified by the tuned amplifier. The instrument thus becomes insensitive to visible light.

It is shown below that, although the total sky radiation may exceed that from a joint, it can be selectively filtered to a negligible value by the use of a glass or mica sector disk.

## THERMAL PROPERTIES OF JOINTS

The total input power to a high-resistance joint consists of two parts, the $I^2R$ power generated internally, and the incident radiation from the sun, called solar radiation.

The power losses are caused by radiation and convection. (Conduction losses were negligible.) The equation is

$$I^2R+P_s=P_r+P_c$$

Or

$$I^2R=P_r+P_c-P_s \quad (1)$$

The bolometer enables only the first term ($P_r$) to be evaluated. The others must be calculated or determined experimentally. Each shall be dealt with separately.

## RADIATION LOSSES ($P_r$)

The radiated power from a cylindrical conductor of length $L$ and diameter $D$ in centimeters has been given[2] as

$$P_r=18.55\times10^{-12}\,LDE\,(T_2^4-T_1^4)\text{ watts} \quad (2)$$

where $E$ = emissivity of the surface, $T_2$ = conductor temperature, degrees absolute, $T_1$ = ambient temperature, degrees absolute.

The emissivity of a body is defined as the ratio of the power radiated per unit area of the material to that radiated by unit area of a perfectly black body at the same temperature.[3] The emissivity of bright aluminum is given as 0.1 or less. A light layer of soot increases $E$ to as much as 0.8. Hence eight times as much power is radiated from a soot-covered joint at temperature $T$ as from a new joint at temperature $T$. On the basis of an investigation by Hutchings and Tuck,[4] lines more than two years old should have $E$ values of 0.5 or higher. Obviously this value will

Figure 2. Bolometer, front end view

depend on the presence of factories, trains, and so on, close to the line. This uncertainty in the value to be ascribed to $E$ may be one of the largest sources of error in calculating the resistance from the temperature.

Using the following typical values in equation 2, then: $T_1=22$ degrees centigrade $=295$ degrees Kelvin; $D=1.8$ inches $=4.6$ cm.; $T_2=50$ degrees centigrade $=323$ degrees Kelvin; $E=0.5$; $L=24$ inches $=61$ centimeters; therefore $P_r=9.2$ watts.

Assuming spherical radiation, the intensity in watts per square foot at a distance of about 70 feet is easily calculated. The power finally incident on the thermistor works out to 38 microwatts. For a sensitivity of 250 microvolts per microwatt, therefore $E_r=9.6$ millivolts, which can be easily measured.

### CONVECTION LOSSES ($P_c$)

In still air the joint is cooled not only by radiation but by natural convection. The air film adjacent to the joint surface becomes heated by conduction and hence rises. These gravity air currents dissipate a considerable portion of the power input to the joint.

Forced convection is caused by a wind which displaces this air film in a horizontal direction causing further cooling. For a joint at 60 degrees centigrade in a 2-mile-per-hour wind the total forced convection heat loss is about four times the radiated power loss.

Curves of natural convection and forced convection losses for various temperatures and wind velocities are calculated for the joint from both theoretical[3] and empirical[4] data.

From the foregoing data it is possible to calculate the total power dissipation $(P_r+P_c)$. If the forced convection is great enough, then it can be reasonably assumed that the natural convection is completely replaced. However for low wind velocities of the order of 0.5 mile per hour the calculated forced convection loss is of the same order of magnitude as the natural convection. Hence, the assumption adopted is to evaluate the combined convection loss by taking the square root of the sum of the squares of both losses. In this way the natural convection is conceived of as a vertical current of air whereas the forced convection is a horizontal current of air.

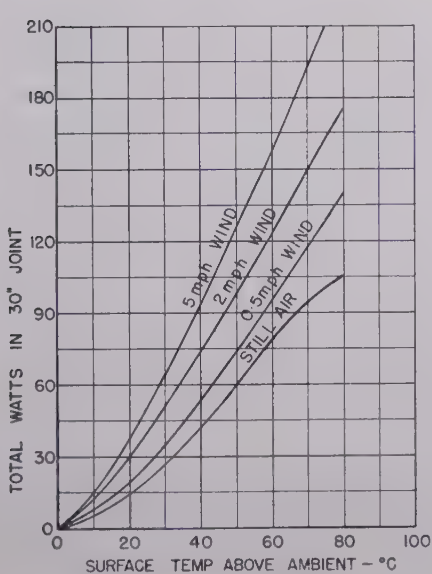


**Figure 3. Power dissipation and temperature rise for a joint**

*Joint diameter, 1.8 inches; emissivity, 0.5*

For a given temperature, the total power being lost from the joint is the sum of the combined convection loss and the radiation loss. For example, when the joint temperature is 60 degrees centigrade, $P_r=14$ watts for an emissivity of 0.5 with an ambient of 22 degrees centigrade. If the wind is two miles per hour, the forced convection loss is 52 watts. The natural convection is calculated as 25 watts. The power loss or total wattage dissipation in the joint will be equal to

$$P_r+P_c=14+\sqrt{52^2+25^2}=72 \text{ watts}$$

In this way a set of curves of total wattage $(P_r+P_c)$ is plotted versus temperature rise for various wind velocities. (Figure 3.)

Using an actual high-resistance joint with currents up to 400 amperes, the calculated wattage dissipation curves were checked to about 10 per cent, which is within the experimental error in measuring wind velocity and other factors involved.

### SOLAR HEATING ($P_s$)

As mentioned, the power input to a joint is equal to the sum of the current heating plus the solar heating. The intensity of solar radiation at the earth's surface neglecting atmospheric absorption is given[5] as 137 milliwatts per square centimeter at right angles to the sun's rays. However, actual measurements on the earth's surface during a clear day indicate values of the order of 100 milliwatts.[6]

Hence the wattage incident on the joint will be the intensity of radiation multiplied by the projected area. The absorption coefficient (emissivity) will be taken as equal to 0.5. If the joint diameter is 1.8 inches (4.6 centimeters) and the length is 30 inches (76 centimeters), then the total wattage absorbed by the joint is given by

$$P_s=0.10\times0.5\times4.6\times76=18 \text{ watts}$$

### SKY RADIATION

The thermistor element "sees" the back of the sector disk on one half-cycle of the disk's rotation and the joint plus a fringe of sky on the other half-cycle. The bolometer measures the difference between the effective temperatures in each case.

To reduce as far as possible the effect of the extraneous sky radiation, it is desirable to make the effective sky temperature equal to the effective disk temperature. Then with the sky reading equal to zero, the bolometer reading will be proportional to the difference of the joint and disk temperatures.

With a clear blue sky, where there is little direct infrared radiation, the use of a polished copper disk was found to result in a low sky reading. The effective temperature of a polished copper disk is very low on account of its low emissivity. This same disk, however, gave an excessive reading on clouds or haze.

With a cloudy sky, either glass, mica, or lithium fluoride disks were used, all giving low readings on a uniform grey sky whether dark or light. The effective temperature of a cloud is lowered with these disks because part of the radia-

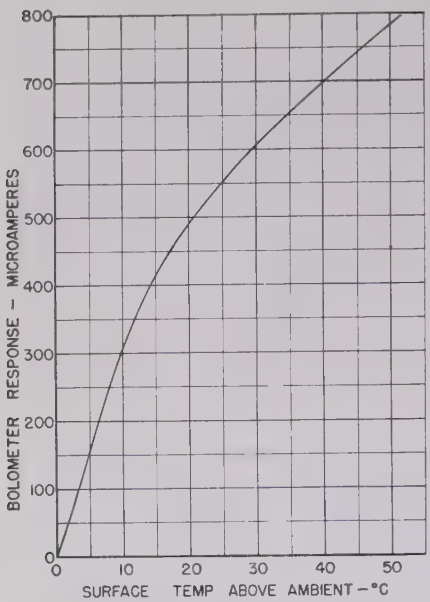


**Figure 4. Bolometer response; valid to ±5 degrees centigrade for distances from 50 to 65 feet**

*Conductor joint, 30 by 1.8 inches; surface color, dark grey*

tion produces a d-c output only, which does not contribute to the reading.

Although the complete explanation is more complicated than this, the experimental data show the same sensitivities for a copper disk and a blue sky as with a mica disk and a cloudy sky. The calibration curves for the infrared radiation are not affected by changing disks because both disks interrupt such rays.

## CALIBRATION

Having been provided with a curve, Figure 3, showing temperature rise above ambient for any wattage loss in the joint, it is only necessary to measure the temperature with the bolometer to enable $I^2R$, hence $R$, to be found. The bolometer calibration curve was obtained experimentally.

Because a high-resistance joint was not available early in the investigation, an artificial "hot" joint was constructed using a standard aluminum compression sleeve with short lengths of conductor (605,000 circular-mils) in which the steel sleeve was replaced with a length of glass-insulated nichrome resistance wire. The ends of this wire were brought out of the sleeve through the holes normally used to insert grease. The surface temperature of the sleeve and the bolometer reading were then obtained for different heater powers.

Figure 4 shows the response of the bolometer to this joint when soot-covered, for various temperatures. Because the image of the joint at the focus is larger than the area of the thermistor flake for this particular joint, the reading is independent of distances over the limits of 35 to 70 feet.

Figure 5 shows the effect on the response of varying the surface finish or emissivity. All the older joints in southern Ontario would be of the blackened type, at least on their under surface. In northern regions this may not be the case. An individual calibration is planned for each typical case.

It was decided also that calibration curves would be desirable for each of the different types of joints, parallel clamps, and so forth. These were simply obtained by heating the latter with a blow torch, then reading the bolometer over a half-hour period as it cooled, the temperature being measured with a thermocouple.

After the first high-resistance joint was found, and cut out of the line, it became possible to obtain a direct check on the radiation- and convection-loss calculations. The joint, of 2,000-microhm resistance, was set up in the laboratory and typical currents were passed through it. The effect of wind cooling on surface temperature was obtained directly

**Table I. Test Results on First Overheated Joints**

| Circuit | Current, Amperes | Wind | Sun | Estimated Temperature Rise, Degrees Centigrade | Calculated Resistance, Microhms |
|---|---|---|---|---|---|
| *Y3T* | 100 | 0 | Bright | 35 | 4,000 |
| *Y3T* | 100 | 0 | Obscured | 30 | 3,000 |
| *B2HS* | 100 | 5 | Bright | 35 | 3,000 |

using a large fan. The curves obtained theoretically in Figure 3 were checked and found to be substantially correct.

## FIELD TESTS

After many preliminary tests, routine measurements were started in August 1948. Readings can be obtained only on days with little or no wind, as the theoretical considerations show that the cooling in a 10-mile-per-hour or higher wind becomes many times the radiation loss. Thus very few joints would run hot on these days. In addition, the accuracy with which the total watts loss can be found is very low with high winds. Of course, the bolometer measures at all times the actual temperature irrespective of wind.

First tests were performed on two double circuit lines ($5^1/_2$ and $6^3/_4$ miles long), both having screw-type compression joints, 110-kv construction, and 477,000 circular-mil ACSR. These lines were placed in service in 1924–25. Three joints (out of 30) showed signs of overheating. The data are given in Table I.

These joints were subsequently cut out and tested in the laboratory. Joint number 1 alone was very high in resistance, measuring 2,000 microhms compared to a normal value of 45 microhms. Joints 2 and 3 were 38 and 96

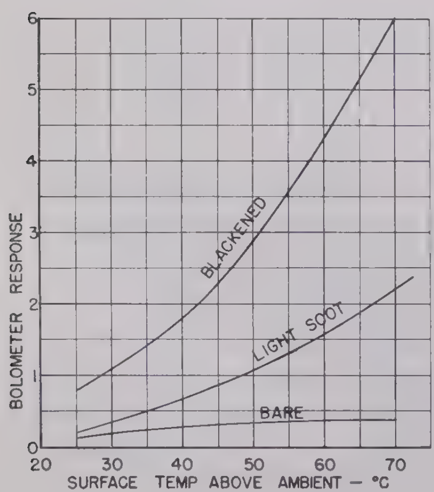


**Figure 5. Effect of surface condition**

microhms, respectively. The latter two were then placed under tension and again measured. Joint 3 was unstable and had then increased to 280 microhms, joint 2 did not change. A current of 200 amperes was then passed through these two joints while still under tension. Joint 3 had increased to over 300 microhms after three days.

Measurements at a much earlier date (1940) on a similar type of high resistance joint showed it to have a resistance inversely proportional to the current. The voltage drop across this joint for heavy currents of different values was constant.

**Table II. Overheated Joints on a 40-Mile Double Circuit Line**

| Tower Number | Test | Wind, Miles Per Hour | Sun | Line Current, Amperes | Estimated Temperature Rise, Degrees Centigrade | Measured Resistance, Microhms |
|---|---|---|---|---|---|---|
| 231 | 1 | 0 | Bright | 280 | 50 | 300 |
| | 2 | 3 | Bright | 130 | 30 | |
| 205 | 1 | 4 | Bright | 150 | 30 | 250 |
| | 2 | 5 | Bright | 280 | 50 | |
| 186 | 1 | 8 | Bright | 200 | 40 | 450 |
| | 2 | 7 | Bright | 180 | 30 | |
| 181 | 1 | 5 | Bright | 200 | 30 | 450 |
| | 2 | 7 | Bright | 150 | 20 | |
| 217 | 1 | 3 | Bright | 130 | 30 | |
| | 2 | 2 | Bright | 270 | 45 | |
| 174 | 1 | 10 | Bright | 200 | 30 | 48* |
| | 2 | 7 | Bright | 200 | 25 | |
| 109 | 1 | 5 | Cloudy | 200 | 30 | 31** |
| | 2 | 4 | Bright | 180 | 30 | |
| 84 | 1 | 8 | Bright | 180 | 30 | 50* |
| | 2 | 4 | Bright | 200 | 35 | |

Total number of joints tested = 310
Conductor = 605,000 ACSR
Ambient temperature = 22 degrees centigrade, approximately
* Measured using lineman's cable seat
** Partially lowered, reached by ladder

It was also noted that joint 3 had been made using a sleeve larger in size than the others (probably a 795,000-circular-mil sleeve). Compressing it originally over the 605,000-circular-mil conductor had cracked the aluminum in two places.

A double circuit line, 26 years old, running from Queenston, Ontario, to Hamilton, Ontario, was tested then. This line of 605,000-circular-mil 40-mile-long ACSR had 310 screw-type joints. They were tested by a 2-man crew in less than two weeks. Eight overheated joints were found, the hottest running at about 50 degrees centigrade over ambient with a line current of the order of 280 amperes. Table II lists these joints, together with their estimated temperature rise, wind velocity, type of sky, and line current. The final column in Table II shows the results of resistance measurements on seven of the eight joints. The line was taken out of service and the resistance obtained from a millivoltmeter reading using 100 amperes direct current. The first four resistances were measured by lowering the conductor to the ground without disturbing the joint. They measured five to ten times normal. Two of the others, which do not measure high in resistance, were measured using a lineman's cable seat. The trolley in passing over the joint may have altered their resistance. The third was partially lowered, then reached by means of a ladder.

It is concluded from these tests that the resistance of a faulty joint is an extremely variable quantity. Removing or increasing the tension or handling of any nature could cause the resistance to vary in an unpredictable manner. This is natural considering that the resistance must lie in thin films of oxide or contamination, these films being easily broken by removing the strains in the material.

Using the value of emissivity and solar heating quoted in the foregoing, these joints were all estimated to have over 1,000 microhms resistance so that the theoretical curves relating watts loss to temperature rise (Figure 3) may be in error. Further experience will enable more accurate curves to be drawn. The arbitrarily chosen value of 0.5 for the emissivity may be high. The effect of solar heating on temperature rise has not been checked experimentally.

## TESTS ON DISCONNECT SWITCHES

Twelve 13.2-kv disconnect switches were tested at the Leaside transformer station. These switches connect four 25,000-kva synchronous condensers to the 220-kv system of The Hydro-Electric Power Commission of Ontario. They were carrying 1,300 amperes at the time of test.

The bolometer was set up about 50 feet from the switching structure and sighted on the contacts. One switch was found to be running at a temperature estimated to be 65 degrees centigrade. The remainder were at less than 30 degrees centigrade. The overheated switch was taken out of service at the earliest opportunity (and found to be still warm one-half hour after the interruption). From the measured resistance, it must have been dissipating about 200 watts across the contact fingers.

## CONCLUSION

Temperature measurements on conductor joints and switch contacts are believed to be rapidly and simply made with the infrared detector described. The accuracy obtained is thought to be better than five degrees centigrade.

The prediction of the power dissipation or resistance of the joint or switch is a much more difficult matter. In fact, there is strong evidence to support the view that these high resistances are an extremely variable quantity, and that temperature rise may be the most reliable index of a joint's condition.

Further studies of the influence of wind cooling, solar heating, and the condition of the surface on temperature rise are indicated.

Application of the bolometer to temperature measurements on rotating parts may be possible.

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# Sequential Aspects of Relay Circuits

A. E. RITCHIE

THE BASIS of relay circuit action is that a set of $n$ of the 2-position devices can assume $2^n$ distinct combinational patterns. Thus a particular input condition can produce a particular relay pattern which, by utilizing the contact configurations on the relays, generates a corresponding output condition. A new input condition develops another output condition, and so on.

Of equal importance with this combinational aspect of relay circuits is the concept that an input combination to a relay circuit can generate an internally used condition which can be locked in for future use. Such internal registrations can be employed to modify the reaction to subsequent input conditions or to originate a series of internally controlled output conditions, which proceed, once started, independent of the input. These considerations all imply a sequential aspect to relay circuits.

Underlying the technique of relay circuit design is an understanding of the basic relay control paths. There are four of these paths, illustrated in Figure 1, which function as follows: operate—the relay operates when contact network, *OP*, closes and releases when *OP* opens; lock-up—when contact network, *LU*, is closed, it prevents the previously operated relay from releasing—it is ineffective before the relay operates; shunt—the relay operates when contact network, *SH*, opens and releases when *SH* closes; and lock-down—when contact network, *LD*, is closed, it prevents the relay from operating—it is ineffective after the relay has operated.

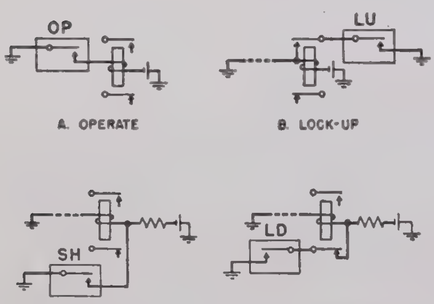


**Figure 1. Basic control paths for a relay**

*Paths shown are: operate; lock-up; shunt; and lock-down*

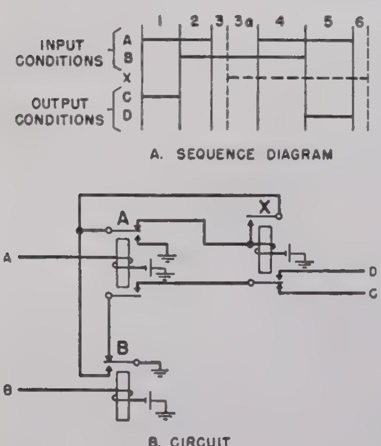


**Figure 2. An example of sequential design**

*Sequence diagram and corresponding circuit are shown*

The nature of input conditions to a relay circuit is clear from Figure 1. In general they consist of the simple presence or absence of ground (or battery) on leads to the circuit. The output conditions which relays can establish are similar to the input conditions in that they consist of the closing or opening of paths.

It is convenient in designing relay circuits to associate a relay with each input path. These primary relays will then accurately follow the various input conditions and offer in effect sets of contacts for manipulation. When the input to a relay circuit involves a sequence of input conditions in which the reaction at each change of input depends upon preceding events, the circuit invariably requires the use of secondary relays whose function is to record the preceding events, to differentiate between repetitions of the same input condition, and to control sequential output conditions. Control of the secondary relays is through contacts on both the primary and secondary relays.

The general design procedure consists, first, of setting up a sequence diagram of input conditions to determine a plan of operation for the secondary relays or, basically, the intervals during which the secondary relays must be operated. Thereafter the control paths and the output paths can be designed on the contacts of the relays. The primary combination to operate a secondary relay must be chosen so that it does not recur at any time during which the relay must be released. Similarly, the release interval may not occur while the secondary relay must be operated

Once the release interval has been established, the holding circuit for a secondary relay can be developed in either of two ways. One is to examine the release interval, determine a path through the primary relay contacts that is open only at that time, and connect the path to a lock-up contact on the relay. The other method is to examine the intervals during which the relay remains operated, determine overlapping contact paths that remain closed until the release interval, and connect such paths in parallel to a lock-up contact. The operate and hold paths are then combined to give the complete circuit for the secondary relay.

A simple example of sequential input conditions is shown in Figure 2*A*. Here, a single secondary relay, *X*, is necessary to differentiate between intervals *1* and *5* in order to produce distinctive output conditions. A corresponding circuit designed on the previously mentioned principles is shown in Figure 2*B*.

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# Counting With Relays

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ELECTROMECHANICAL relay circuits, which recognize the appearance and disappearance of electric pulses representing events to be counted and which establish unique conditions during and after each successive pulse, or after a particular number of pulses, are termed relay counting circuits. With such circuits, the number of preceding events can be determined by the operated combination in which the relays comprising the circuit stand. Electrical paths through the contacts of these relays may therefore represent digits in a numerical system.

To detect the passage of a single pulse, three distinct conditions must be recognized: prepulse; during pulse; and postpulse. As relays are 2-positional devices, two relays are necessary to produce the three unique combinations that can be placed in one-to-one correspondence with the three conditions. A method of obtaining this end is shown by the first vertically arranged relay pair of Figure 1. Closure of a ground pulse to lead *P* operates relay *1* which then locks operated. Relay *1'* cannot operate, for ground is now placed on both terminals of its winding. At the termination of the pulse, relay *1'* operates and holds to relay *1*. Thus the prepulse condition found no relays operated, the during pulse condition, one relay, and the postpulse condition, two relays operated.

The problem of counting a train of pulses immediately suggests the cascading of single-pulse counters as shown in Figure 1. The resultant circuit will then not only be capable of counting the number of pulses represented by the maximum number of relay pairs so cascaded, but will count a train of any number of pulses less than this maximum. This is because the circuit holds its relays as set by the last received pulse.

As the prepulse interval of every pulse except the first overlaps the postpulse interval of the preceding pulse, the circuit of Figure 1 may appear wasteful of apparatus. The minimum number of intervals required, or number of relay combinations, is $2P + 1$, where $P$ is the number of pulses.

As two relays can be operated in four combinations and three relays in eight, the number of combinations in which $N$ relays can be operated is $2^N$. Now if a circuit is to count a number of pulses, $P$, a number of relays, $N$, such that $2^N$ is equal to or greater than $2P + 1$, is the minimum required.

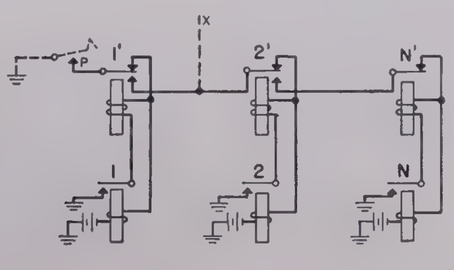


**Figure 1. Relay scheme for counting with prime pairs**

Circuits based on a minimum number of relays and which use a large portion of the possible relay combinations tend to produce large spring loads and complex contact circuits for their own control. Add to this the number of relays which must be examined at any stage to determine the count and the spring load becomes excessive.

Other schemes of counting offer a more practical means of reducing the required number of relays. One method is to utilize common detecting of each pulse and to provide additional means for recording. A circuit using a "pulse divider" for pulse detection and single relays for recording each pulse is shown in Figure 2. Operating much like the "counting pair" on the first pulse, the pulse divider causes the second pulse to release relay *Z* by shunting its winding and to hold relay *W* until the termination of the pulse. The pulse divider then returns to normal and is ready for the next pulse. A transfer on relay *Z* directs operation of the proper recording relay.

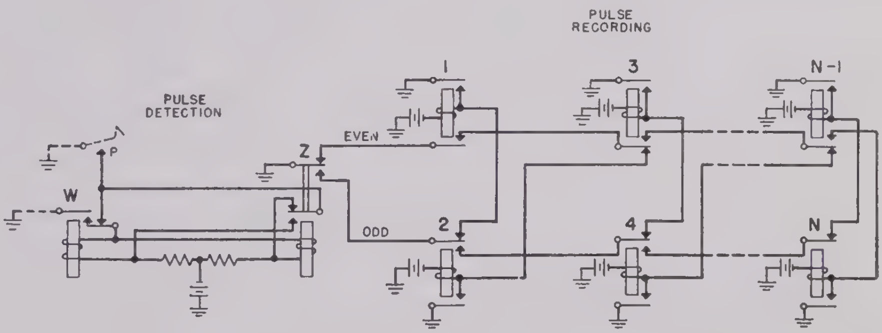


**Figure 2. Separation of detecting and recording functions in pulse counting**

The type of counting circuit utilized in practice depends upon the count information required. Where information must be supplied to external circuits after a particular number of pulses have passed, the number of relays that must be examined to determine only this one number is of no concern. Therefore, "minimum relay" circuits may be used. The $2P-1$ value should, however, be exceeded sufficiently to produce practical spring loads.

The necessity for establishment of unique conditions either during or at the termination of each pulse is more readily satisfied by the counting pair or common detecting and recording types of circuits.

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# Carrier for Relaying and Joint Usage—I

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CARRIER relaying is useful principally, but not exclusively, for speedy clearing of ground faults. If ground faults, even though limited in current, are not cleared promptly, an extended fault arc frequently involves another phase conductor and even another line. Also, static wires or conductors may be damaged so as to break, particularly under ice loading. In the near future, relay schemes must be adapted to lines with taps or automatic reclosing or both.

Carrier channels and equipment can be shared between various functions, such as relaying, communication, telemetering, and so forth, in varying degrees with corresponding advantages and disadvantages. Most carrier relaying schemes have provisions for limited nonrelaying usages, which tend to lead to some wastage of carrier energy and spectrum space and to some relaying hazards in the form of incomplete control of carrier by the primary relays. When communication is kept as a separate function on separate equipment, it is often less than adequate when most needed, as in bad weather. In contrast, the extra care applied to relay channels becomes available to communication under joint usage.

Carrier channels may be classified as to types of signal control or modulation or the combination of the two. The main principles are keyed carrier, amplitude modulation, frequency modulation, and narrow band frequency shift, but there are important subtypes and adaptations of these, such as the single side-band type.

Carrier transmission and reception involves attentuation, interference (several types), and distortion problems. These can be discussed qualitatively, but quantitative knowledge is meager; hence, standardized test data are badly needed. In comparing carrier types or systems, there are distinctive characteristics in each which may be advantageous, both as to function and performance. The same is true of the forms of coupling and trapping. In attempting to choose between competitive systems it appears that there are undeveloped potentialities in them, both singly and in combination. It seems fairly obvious, however, that using a full-width carrier channel exclusively to transmit a simple on–off signal will meet increasing resistance from economic considerations and carrier spectrum crowding.

The nonrelay usages vary in their requirements, making each application a separate problem. The extent of joint usage, or at least the detailed layout of the equipment, must in some cases consider maintenance problems.

One disadvantage in having relay carrier (or a tone) held on for relaying or any other purpose, such as signal strength tests, or measurements for sleet detection, is that on–off control of the signal by relay elements must be provided at both terminals when a fault occurs. Figure 1 shows an example of loss of relay control. The remote end circuit breaker opened promptly from the instantaneous (noncarrier) ground relay. The local end did not furnish enough ground current to actuate the carrier control relays. The received carrier ceased momentarily, but, as soon as the remote circuit breaker opened, the carrier stopping relay at that end reset, and carrier was again transmitted from the remote terminal and received as shown. The local circuit breaker would have been opened by the ground backup relay, but meanwhile the arc extinguished of its own accord as seen in the neutral current trace. The local circuit breaker did not open.

The same difficulties can be encountered if carrier is transmitted from the no source end for telemetering, communication, or even push-button tests. Inquiries have revealed that, in some utilities that use carrier for relaying, this aspect of joint usage on standard equipment is not recognized, or at least not fully evaluated. The objectives in seeking improved carrier schemes, which may involve joint usage in varying degrees, are to meet new problems which have arisen in the relaying field, to provide better nonrelaying services, to alleviate spectrum crowding, and to reduce installation and maintenance costs.

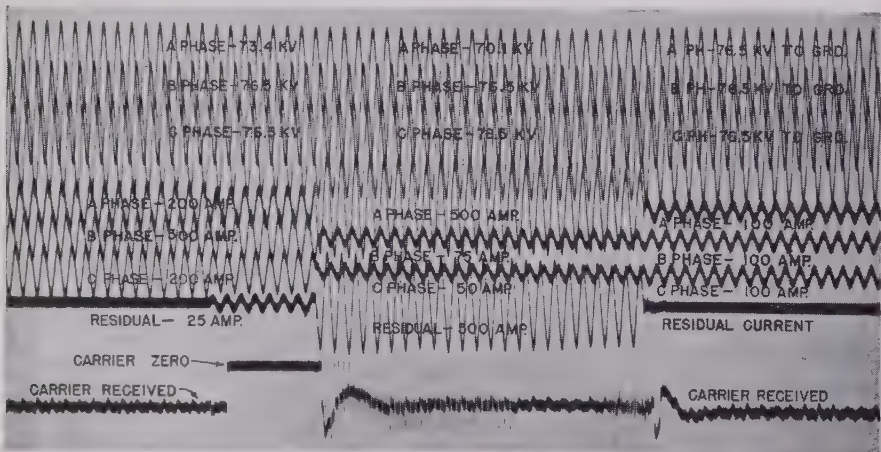


**Figure 1. A record of a fault in which relay control of carrier was lost when the line opened at the remote end, the carrier initially being held at that end for glaze detection**

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# Crystal Orientation in Magnetic Alloys

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**For many magnetic alloys, the permeability is strongly dependent on crystal orientation. Three per cent silicon-iron and 48 per cent nickel-iron alloys are described, wherein the cube edge of the crystals are aligned with the rolling direction of the sheet, thus permitting utilization of the superior permeability in the cube-edge direction of the crystals.**

THE MAGNETIC permeability of a crystal of the most common magnetic material, iron, is not uniform in every direction but varies considerably depending on the direction of the magnetic field with reference to the crystallographic axes of the crystal. This is also true for many magnetic alloys; in the case of a three per cent silicon-iron alloy, the flux-carrying capacity of a single crystal in its best direction is about 65 per cent greater at an applied magnetizing force of ten oersteds* than its capacity for the same magnetizing force applied in its worst direction.

The data of Williams[1] for a single crystal of 3.9 per cent silicon iron shown in Figure 1 are an excellent illustration of the variation of permeability with crystallographic axis. The cube edge, or (100) direction by Miller indexes, has nearly uniformly superior permeability over a wide range of magnetizing forces from about 1 to 50 oersteds. The effect of orientation does not disappear until the material is virtually saturated magnetically.

If it were possible to assemble a test specimen of many crystals of a magnetic alloy such as three per cent silicon-iron and not favor any particular orientation, the permeability of such a polycrystalline sheet would be uniform in every direction. The permeability value of this hypothetical randomly oriented or unoriented sheet would be slightly better than that of the face diagonal or (110) direction of a single crystal. Knowing the easy magnetization of the (100) direction, a more interesting experiment would be to arrange matters so that the cube edges of all the component crystals in a polycrystalline specimen were parallel and in the plane of the sheet. Theoretically such a specimen would have one-third greater flux carrying capacity in its best direction than an unoriented specimen. Translated in terms of a transformer this would allow a proportionate reduction in core weight in addition to savings in copper windings, tank size, and so on.

The achievement of this goal of producing a polycrystalline magnetic material with properties resembling those of a single crystal was first realized in the United States in the early 1930's when Goss produced a three per cent silicon-iron which had greatly improved permeability in the rolling direction. Recently, through information obtained by the United States Navy in Germany at the close of World War II, considerable interest has developed in an oriented nickel-iron alloy. The Germans perfected the production and utilization of this alloy during the war although the method of obtaining the desired orientation already had been disclosed by Dahl and Pfaffenberger in 1931.[2] These two alloys, the three per cent silicon-iron and 50 per cent nickel-iron, are the two principal oriented magnetic materials manufactured and used today. Their use is relatively new and expanding rapidly.

One of the most useful and informative methods of evaluating the crystal orientation is to etch the material chemically so that the facets of the pits produced are parallel to some particular crystallographic plane. It is possible to develop pits revealing the cube face or (100) family of planes in both the alloys mentioned. Figure 2 is a sketch of the appearance of a polycrystalline sheet after etching and

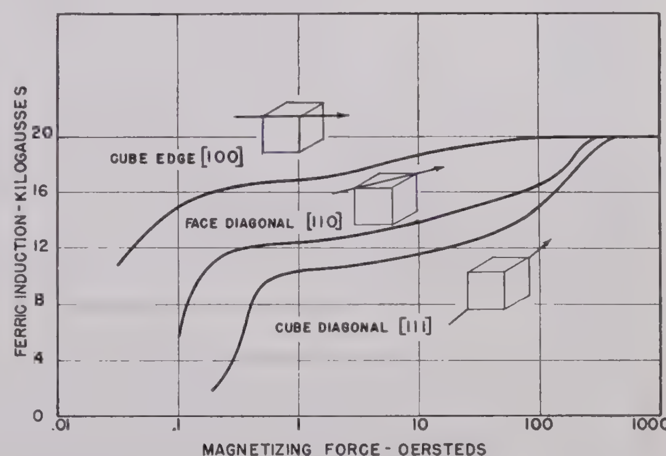


**Figure 1. Effect of crystallographic direction on magnetization of a silicon-ferrite crystal**

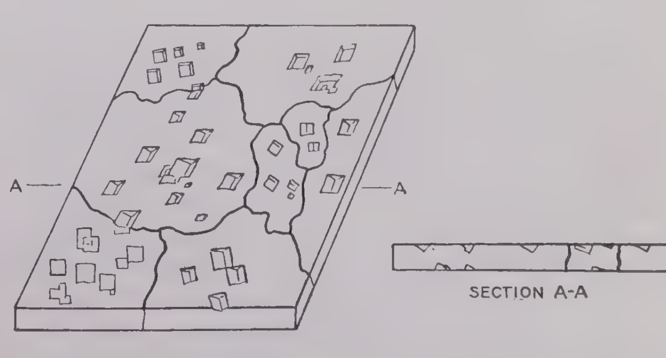


**Figure 2. Diagram of a sample etched to develop (100) planes**

Full text of a conference paper presented before the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949.

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*A magnetizing force of ten oersteds corresponds to about 20 ampere-turns per inch.

**Figure 3. Pitting in silicon ferrite X1,000**

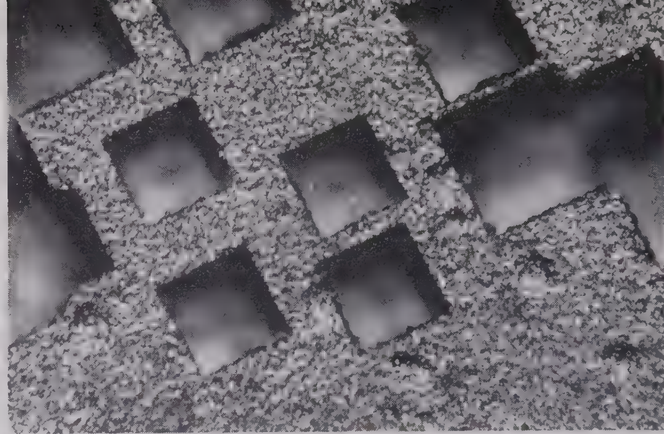

**Figure 4. Pitting in silicon ferrite X1,000**

Figures 3 and 4 are photomicrographs, taken at a magnification of 1,000, of pits actually obtained in silicon ferrite. Since there are only three mutually perpendicular planes which develop for each crystal, their study is relatively simple and can be determined quantatively with an optical goniometer which instrument operates on the principle of light reflection from the cube-face etch pits.

A convenient method of presenting the data obtained on the optical goniometer is the use of the stereographic projection. As shown in Figure 5, the stereographic projection may be represented as being derived by two simple steps. Considering a crystal located in the center of an imaginary sphere, the first step consists in locating the intersections of the normals (solid lines) to the cube faces of the crystal with the surface of the sphere. Then the stereographic projection of these points is determined by the interesections with the equatorial plane with lines (shown dotted in Figure 5) drawn from the projection points on the surface to the south pole of the sphere. In rolled sheet materials it is customary to use the direction of rolling (R.D.) as the reference direction and the sheet surface, that is the rolling plane, as the plane of the projection.

To acquaint the reader with a few simple examples of the representation of orientation with the stereographic projection, a series of three positions is shown in the diagrams of Figure 6.

Figure 7 shows the orientation texture of a typical high-silicon sheet produced by pack hot rolling. Each point represents the pole of one crystal face and three mutually perpendicular poles represent one crystal. Although the centers of gravity of the six groups of points correspond roughly to position number 2 and its mirror image in Figure 6, it hardly would be correct to state that position number 2 represents the orientation since some crystals deviate by as much as 40 degrees from this mean position. Note that the macrostructure of the grains in the specimen shown does not give any particular clue as to the type or perfection of the crystal-orientation texture present. The variation in permeability at ten oersteds in the plane of the sheet at various angles is shown by the polar graph. The permeability is comparatively low in all directions and has its highest value at an angle of about 38 degrees from the rolling direction where the cube edges of the crystals are most nearly in the plane of the sheet.

A pole figure of highly oriented three per cent silicon iron is shown in Figure 8. In this case the crystals tend to have a cube edge in the rolling direction and a face diagonal in the transverse direction. A cube diagonal direction, accordingly, will be found to be about 55 degrees from the rolling direction in the plane of the sheet. The orientation is commonly referred to as the "cube-on-edge" type. Of course, this type of material must be used with the magnetizing force parallel to the rolling direction as is indicated by the polar graph of permeability. It is interesting to note that the macrostructure of this oriented specimen is hardly different from the higher silicon hot-rolled specimen of Figure 7. The terms "with grain" (referring to the rolling direction) and "across grain" or "transverse grain" (referring to the transverse direction) are therefore really incorrect terminology although they are commonly used in connection with magnetic testing.

The iron-nickel alloy shown in Figure 9 was selected because of the interesting combination of orientations present. These may be divided into three easily distinguishable groups. The fine-grained matrix represented by the small dots consists of an extremely well-developed texture with one cube edge parallel to the rolling direction and another parallel to the transverse direction. This fine-grained matrix may

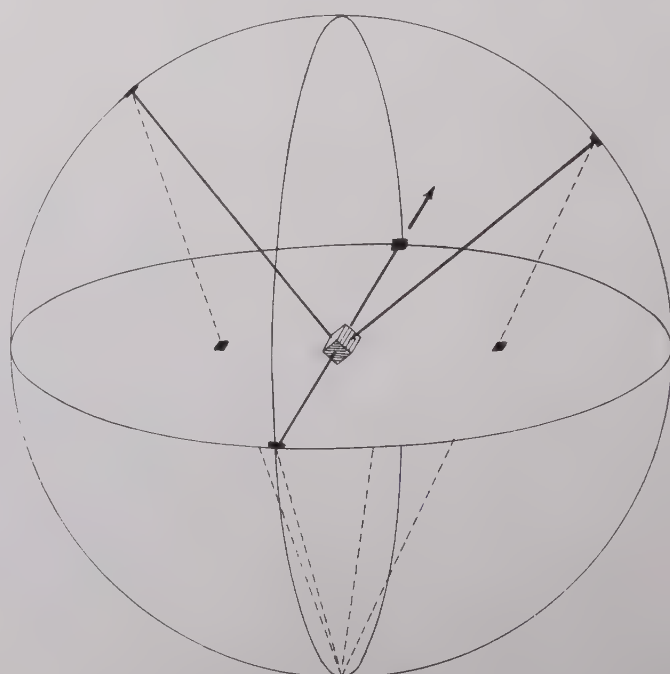

**Figure 5. Derivation of (100) pole figure**

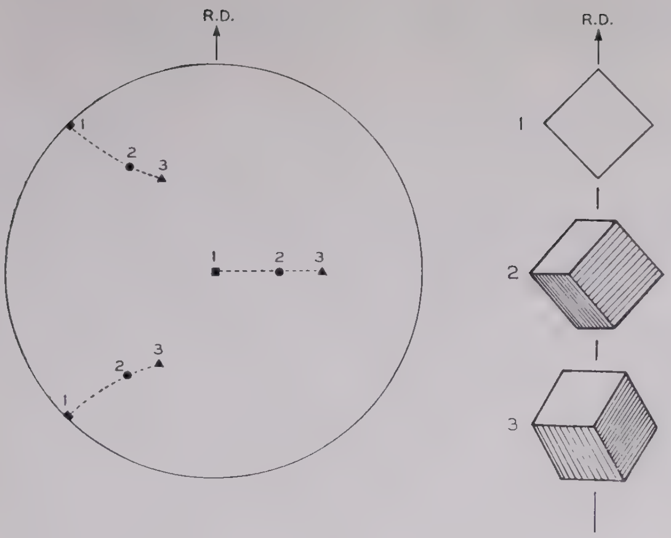


Figure 6. Representation of orientation with stereographic projection

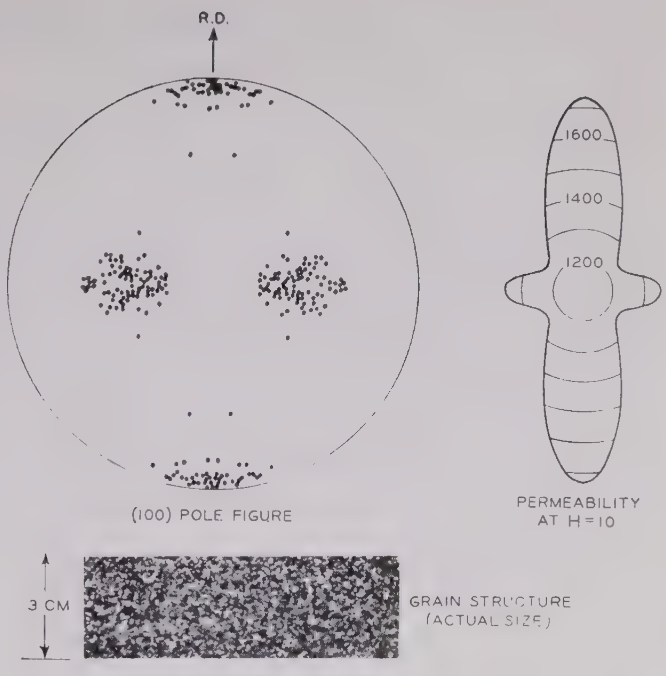


Figure 8. Oriented 3.2 per cent silicon iron

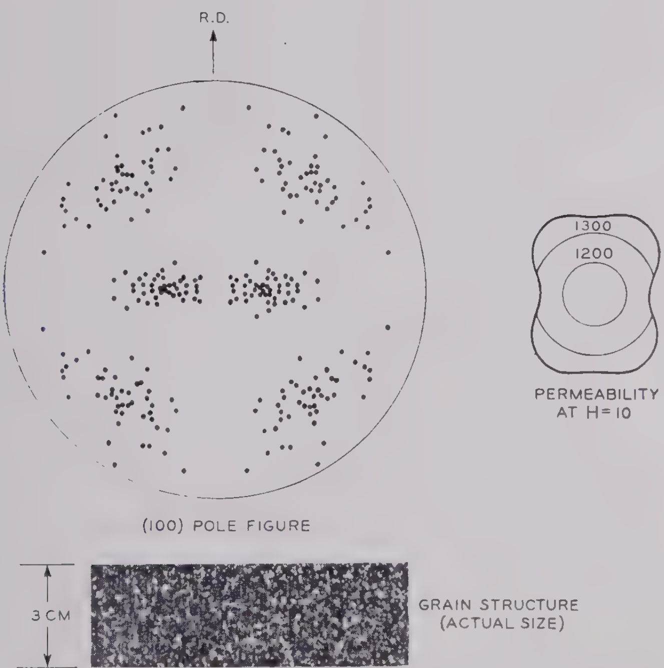


Figure 7. Hot-rolled 4.7 per cent silicon iron

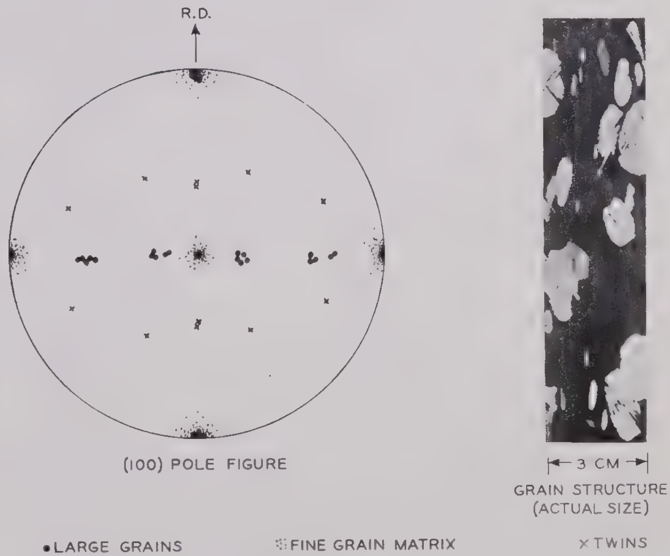


Figure 9. Oriented 48 per cent nickel iron

be recognized as the dark background in the photomacrograph shown in Figure 9. The large grains have an orientation which differs from the small grains by rotation of about 20 degrees either way with the rolling direction as an axis. Within the large grains are wedge- and needle-shaped twins which tend to have a cube diagonal parallel to the rolling direction. Of course, such twins are undesirable since they would lower the permeability in both the rolling direction and the transverse direction.

The commercial oriented nickel alloys are marketed under such names as Orthonik, Permeron, and Deltamax. These alloys are useful because they possess the characteristic of becoming virtually saturated with very small magnetizing force. This is a result, primarily, of the very highly developed crystal orientation of the type shown by the fine grained matrix of Figure 9.

The development of oriented magnetic materials, their production and application is a remarkable story of the joint efforts of the research metallurgist, the men who make steel, and the electrical engineer. The use of oriented magnetic alloys is now nearly ten years old but the field of application in America's rapidly growing electrical industry appears still to offer unlimited opportunity.

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# Logic of Relay Circuits

WILLIAM KEISTER

REQUIREMENTS for relay circuits are usually stated on a cause and effect basis; that is, when certain events occur in a particular way, certain effects will be produced. If a clear logical statement of relations between causes and the desired effects can be made, a circuit of relays controlled by contact networks can be constructed which is analogous to the logical statement and consequently produces the desired results. A machine incorporating such circuits "knows" what to do for a definite set of circumstances; it is able to analyze a combination of preconceived conditions and produce a result which agrees with the basic pattern of logic laid out by the designer.

A pair of mating contacts is called, in this article, simply a contact. At any given time a contact is either open or closed and thus corresponds to an "open or shut" proposition in logic which is demonstrated under given circumstances to be either false or true. A 2-terminal network of contacts corresponds to a proposition whose truth or falsity depends on the truth or falsity of several subordinate propositions, the subordinate propositions corresponding to contacts in the network. Furthermore, the arrangement of contacts in a network is similar to the way subordinate propositions are related to prove a given proposition true or false. To exemplify: the lighting of a lamp may depend on the position of switches *A* and *B*. The statement that the lamp lights when "*A* is operated *and B* is operated" clearly indicates a series connection of make contacts on *A* and *B*. Similarly, "*A* is operated *or B* is operated" indicates a parallel connection. A more complex statement, "*A and*, *B or C* operated," indicates the series-parallel circuit of a contact, *A* being in series with the parallel combination of contacts *B* and *C*. Thus, in a careful statement of conditions for closing a circuit, *and* represents parallel, while *or* represents series connections.

This is illustrated by a version of the "wolf, goat, and cabbage" puzzle: A farmer entrusts the care of a wolf, a goat, and some cabbages to a not-too-intelligent hired man. The items are kept in one or the other of two barns. Obviously, the hired man must not leave the wolf with the goat, nor the goat with the cabbages. To check on the hired man, the farmer desires a device consisting of keys, *W*, *G*, *C*, and *M*, representing, respectively, the wolf, goat, cabbages, and hired man. Observing the contents of one barn and operating the corresponding keys, the farmer is warned by the lighting of a lamp if the hired man is not fulfilling his duties.

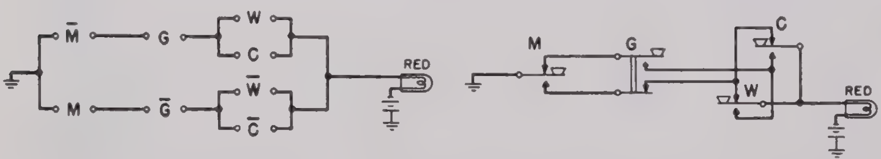


**Figure 1. Alarm circuit: network shown at left; schematic at right**

First, consider the situation in a particular barn. If the hired man is not present and the goat is present with the wolf or the cabbages, trouble occurs in that barn. A more concise statement is "*M* absent *and G* present *and*, *W or C* present." Items absent from one barn must be present in the other so that a similar statement concerning items not observed describes conditions for trouble in the other barn. The statement is "*M* present *and G* absent *and*, *W or C* absent." Networks are constructed from these statements, "present" indicating a make contact and "absent" a break. Since trouble occurs if one *or* the other of these statements is true, the two networks are placed in parallel. This is shown in Figure 1 (left), a bar over a designation indicating a break contact. The equivalent schematic is shown at the right. With this device it is necessary only that a person be able to identify the items in one barn. No analysis of the habits of wolves or goats is required. The contact network having been developed to correspond to a logical framework will examine input conditions to produce answers according to this logic.

Now suppose that the farmer, after using the device for some time and losing a quantity of cabbages due to a burned-out warning lamp, requests that a green lamp be also provided to indicate as a check that conditions are satisfactory. Thus, the red lamp will light when the hired man is in trouble and the green lamp when the situation is under control. For this circuit we may simply construct the negative of Figure 1 without further analysis of the problem. An experienced designer will combine and rearrange the complete circuit for both lamps in the equivalent form. We leave to the reader the design of a suitable carrying case for the device.

In this example there is a fixed correspondence between combinations of control conditions and the output condition. In circuits of a higher order of complexity, output conditions depend not only on the input conditions then present, but also the sequence in which previous control conditions have occurred. In any automatic control mechanism employing relays controlled by networks of contacts, the control means for any one relay is equivalent to a 2-terminal network which, in turn, is equivalent to a statement of the conditions which must cause the relay to operate.

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# Significance Tests of Engineering Data

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**Probability functions are essential aids in the evaluation of data. Using them, the significance of differences between standard and observed values can be determined. Furthermore, they provide a means of checking agreement between practice and theory. Thirdly, the function known as variance will tell the engineer what factors are contributing to deviations in items that do not conform very exactly to their design.**

THE DEVELOPMENT of new products in the measurement field as in many other lines requires a considerable amount of experimental testing before the factory is asked to carry on the work of manufacturing a specified design. The data accumulated in these tests are the basis for many decisions as to the materials and processes to be employed in making the new device. Evidence is sought to warrant the proper selection and strong enough evidence to obviate any later changes. Some decisions necessarily are made with a minimum number of tests because of the cost of the experiment or the nature of the function being studied. It is desirable to know the margin of safety on these close judgments and the probability of success.

Statistical tests are designed to evaluate these very factors. Calculated risks are the business of the statistician and his usefulness in industry is logical and economical. This branch of mathematics has a place in engineering lore along with other scientific procedures. The necessary sequence of steps in the analysis very forcefully points up the direction of the work and the logic of the conclusion.

Furthermore, whether or not statistical methods are used, case histories are found in the literature describing a test in which an analysis of variance is made, or one in which $X^2$ is used as a criterion for judging some distribution. One can be very much at sea or lose altogether the impact of such statements unless one understands the language of the statistician indicating the underlying critique employed in making his decisions.

Mathematical models of probability functions are as important in their place as the familiar sine curve for a-c phenomena or the hyperbola for studying pressure and volume relationships with gases. Experimental data are set against these models to determine the extent of agreement and to pick out departures from normality when they appear. The Gaussian curve (Figure 1) defined by the equation

$$y=\frac{1}{\sigma\sqrt{2\pi}}\epsilon^{-\frac{1}{2}\frac{(X-\bar{X})^2}{\sigma^2}}$$

is a true picture of the distribution of very many measured characteristics. The biologists give the area under this curve the name "population" and a sample from this parent group, or lot, more or less faithfully mirrors the model according to the sample size. Deviations from the nominal or average value are called chance or random errors, not in the sense of the philosopher, to whom a chance event rarely happens and cannot be predicted, but rather in the sense of being the result of a multiplicity of unidentified causes contributing now this direction and now another but averaging a predictable value.

In industry, design specifications are the master key or model against which the factory grinds out duplicates that will follow the prototype closely enough to accomplish the designer's purpose. Development testing is aimed at predicting how closely the device can be replicated and what factors need to be controlled to assure homogeneity. Hence, we arrive at the necessity of significance levels for the evidence supplied by engineering data.

Typical of one class of problem where the question is, "How well do two groups of data agree on the average?", is chemical analysis of sulphur content. The laboratory acquired a Sulphur Determinator and the chemist made a few test runs on samples with standard sulphur contents. After testing five standard samples and looking at the differences between what he observed and standard values, he wants to know if they are significant (Table I).

The $t$ test used to evaluate these observed differences consists of a distribution of means of small samples in standard error units tabled against the probability of getting such a difference. For a sample of five with four degrees of freedom, the probability of $t=0.119$ is greater than 90 per cent (Table II). In other words, five samples

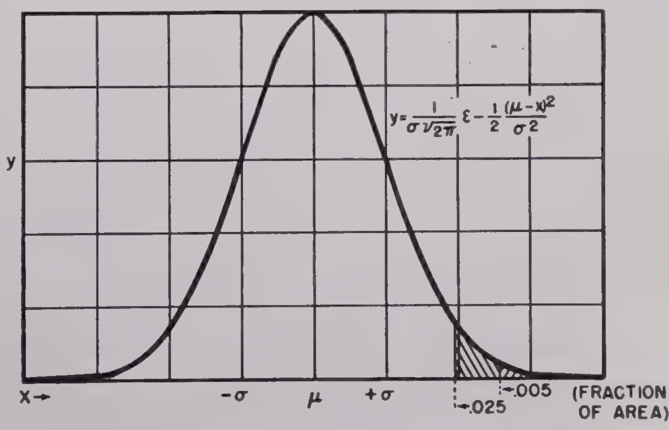


**Figure 1. Gaussian curve of normal distribution**

Full text of a conference paper, "Significance Tests on Engineering Data," presented at the Conference on Statistical Applications held during the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949.

**Paul E. Thompson** is with the General Electric Company, West Lynn, Mass.

**Table I. Stated and Observed Percentages of Sulphur in Standard Sample**

| Standard | Observed | Difference | $(d-d_{av})^2$* |
|---|---|---|---|
| 0.025 | 0.026 | +0.001 | 0.00000036 |
| 0.036 | 0.038 | +0.002 | 0.00000256 |
| 0.047 | 0.048 | +0.001 | 0.00000036 |
| 0.032 | 0.030 | −0.002 | 0.00000576 |
| 0.080 | 0.080 | 0.000 | 0.00000016 |
| Totals | | +0.002 | 0.00000920 |

$$d_{av}=\frac{0.002}{5}=0.0004$$

$$*\sigma=\sqrt{\frac{\Sigma(d-d_{av})^2}{n-1}}=\sqrt{\frac{0.00000920}{4}}=0.0015. \quad \text{Then, } t=\frac{d_{av}}{\hat{\sigma}\sqrt{n}}=\frac{0.0004}{0.0015\sqrt{5}}=0.119.$$

from a lot of homogeneous material would have in the long run more than 90 per cent of the time differences as great or greater than those here observed. The chemist then has assurance that the results of his determination are not significantly different from the standard value.

The technique is the same for more involved questions whenever assurance is sought that an average value of a substitute material is or is not significantly different from a standard, or that a new process or design agrees with requirements. And in any of these cases the risk associated with the decision can be set in accordance with the economic factors involved.

Another statistic of some importance in evaluating an observed frequency distribution is $X^2$, a measure of agreement between theory and practice. In practice, we set such a distribution against a known one, or a calculated set of theoretical frequencies, to measure the significance level of the disparity. In the heat-treating of pivots, for example, tests were run to find if some improvement in hardness was obtained by a quick quench. Thirty-six pivots from each of two procedures were tested for hardness and tabulated above and below a Knoop number of 800 (Figure 2). The conclusion is fairly obvious from this data that quenching improves the hardness. But 36 is a small sample with which to predict the effect on thousands of pivots, and the probability associated with the value of

**Hardness of Pivots**

| Knoop Number | Not Quenched | Quenched | Totals |
|---|---|---|---|
| >800 | (20) 15 | (20) 25 | 40 |
| <800 | (16) 21 | (16) 11 | 32 |
| | 36 | 36 | 72 |

**Figure 2. Analysis of heat-treating methods using $X^2$**

$$X^2=\Sigma\frac{(a-t)^2}{t}=\frac{(15-20)^2}{20}+\frac{(25-20)^2}{20}+\frac{(21-16)^2}{16}+\frac{(11-16)^2}{16}=5.625;$$

$P<0.02$

$X^2$ gives the assurance desired for maintaining the process. More complex scoring can be done with $X^2$, and it is also used to set confidence limits for the standard deviation estimated from samples.

The third statistic, and the last one, to be treated in this brief survey of analytical aids for engineers is $F$, the variance ratio. Variability is a condition which everyone encounters and with which we have to contend in our attempts to make a number of identical things. Every advance in precision both of the product and of the tools for making it tends to mask some of the influences that cause trouble. It is frequently necessary to make an experiment with several samples to arrive at some knowledge of what is taking place. The data thus obtained must be analyzed to separate the elements of variability involved. In order to arrive at a statement of conclusions that is not ambiguous nor without limits, it is helpful to arrange an intelligent program for getting the right amount of the right kind of information. Designed experiments using the $F$ ratio are frequently the most direct approach to isolating causes of trouble.

Analysis of variance connotes a specific function to the statistician, since variance is $\sigma^2$ or the quantity of which the standard deviation is the square root. In practice, observed variance in a product may be composed of several factors such as the operator, machine, day of the week, and the like. Test runs are made in such a way that the over-all variance can be apportioned to the proper sources and a quantitative comparison made to measure significance. One of these component variances will be residual or unallocable. If it is a small portion of the total, the others are presumably the trouble-makers and their magnitude ratioed with the residual variance gives a measure of their significance in terms of $F$. Tables of $F$ then give the probability level at which their importance is asserted.

One form of designed experiment well suited to study of problems involving a number of combined factors is the Graeco-Latin square. There are four fundamental steps in applying this procedure: firstly, the application of sound engineering

**Table II. Probability of $t$ Versus Degrees of Freedom**

| Degrees of Freedom | P=0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.158 | 0.325 | 0.510 | 0.727 | 1.000 | 1.376 | 1.963 | 3.078 | 6.314 | 12.706 | 31.821 | 63.657 |
| 2 | 0.142 | 0.289 | 0.445 | 0.617 | 0.816 | 1.061 | 1.386 | 1.886 | 2.920 | 4.303 | 6.965 | 9.925 |
| 3 | 0.137 | 0.277 | 0.424 | 0.584 | 0.765 | 0.978 | 1.250 | 1.638 | 2.353 | 3.182 | 4.541 | 5.841 |
| 4 | 0.134 | 0.271 | 0.414 | 0.569 | 0.741 | 0.941 | 1.190 | 1.533 | 2.132 | 2.776 | 3.747 | 4.604 |
| 5 | 0.132 | 0.267 | 0.408 | 0.559 | 0.727 | 0.920 | 1.156 | 1.476 | 2.015 | 2.571 | 3.365 | 4.032 |
| 6 | 0.131 | 0.265 | 0.404 | 0.553 | 0.718 | 0.906 | 1.134 | 1.440 | 1.943 | 2.447 | 3.143 | 3.707 |
| 7 | 0.130 | 0.263 | 0.402 | 0.549 | 0.711 | 0.896 | 0.119 | 1.415 | 1.895 | 2.365 | 2.998 | 3.499 |
| 8 | 0.130 | 0.262 | 0.399 | 0.546 | 0.706 | 0.889 | 1 108 | 1.397 | 1.860 | 2.306 | 2.896 | 3.355 |
| 9 | 0.129 | 0.261 | 0.398 | 0.543 | 0.703 | 0.883 | 1.100 | 1 383 | 1.833 | 2.262 | 2.821 | 3 250 |
| 10 | 0.129 | 0.260 | 0.397 | 0.542 | 0.700 | 0.879 | 1.093 | 1.372 | 1.812 | 2.228 | 2.764 | 3.169 |
| 11 | 0.129 | 0.260 | 0.396 | 0.540 | 0.697 | 0.876 | 1 088 | 1.363 | 1.796 | 2.201 | 2.718 | 3.106 |
| 12 | 0.128 | 0.259 | 0.395 | 0.539 | 0 695 | 0.873 | 1.083 | 1.356 | 1.782 | 2.179 | 2.681 | 3.055 |

| | I | II |
|---|---|---|
| A | 1 | 2 |
| B | 2 | 1 |

2 by 2 Square

| | I | II | III |
|---|---|---|---|
| A | 1 a | 2 b | 3 c |
| B | 2 c | 3 a | 1 b |
| C | 3 b | 1 c | 2 a |

3 by 3 Square

| | I | II | III | IV |
|---|---|---|---|---|
| A | 1 a α | 2 b β | 3 c γ | 4 d δ |
| B | 2 c δ | 1 d γ | 4 a β | 3 b α |
| C | 3 d β | 4 c α | 1 b δ | 2 a γ |
| D | 4 b γ | 3 a δ | 2 d α | 1 c β |

4 by 4 Square

| | I | II | III | IV | V |
|---|---|---|---|---|---|
| A | 1 a α v | 2 b β w | 3 c γ x | 4 d δ y | 5 e ε z |
| B | 2 c δ z | 3 d ε v | 4 e α w | 5 a β x | 1 b γ y |
| C | 3 e β y | 4 a γ z | 5 b δ v | 1 c ε w | 2 d α x |
| D | 4 b ε x | 5 c α y | 1 d β z | 2 e γ v | 3 a δ w |
| E | 5 d γ w | 1 e δ x | 2 a ε y | 3 b α z | 4 c β v |

5 by 5 Square

**Figure 3. Graeco-Latin squares**

principles to select the variables that appear influential; secondly, the design of the experiment from which the data are to be obtained; thirdly, the actual work of testing and the recording of data; fourthly, the mathematical treatment of the data to measure the relative importance of the separate factors. Assuming that the problem has been defined clearly and the critical region of variability properly selected, the statistician arranges a plan of action. Then, accepting as truly representative the data obtained, he derives the conclusions concerning the importance of each element.

Examples of such designs are shown in Figure 3. The arrangement is essentially a device for selecting certain combinations of the variables to measure the contribution of each one to the total variance. A square will accommodate one more variable than there are stages of variation. In other words, a three-by-three square allows the combining of four variables with three steps in the values of each one. Classical methods of testing such a complexus would require 81 combinations whereas the designed experiment selects nine of these and obtains a measure of the individual influences.

A case in point was the temperature compensation of dual tachometer indicators for aircraft. Four contributing factors were: location of the compensator plate; conductivity of the drag disk; coefficient of conductivity of the disk material; thickness of the compensator plate. Three values of these in the critical region were chosen and coded to a three-by-three square as shown in Figure 4. Each setup was duplicated for a measure of repeatability. Errors were tabulated at various temperature levels and the analysis aimed at finding the arrangement that would produce least error. The data shown were read at −22 degrees centigrade and similar work was done at +49 degrees centigrade, −37 degrees centigrade, and −56 degrees centigrade. The final tabulation of results is shown in Table III. With only nine tachometers, it was possible to show that conductance values were a more critical indicator for properly locating the compensator plate than thermal coefficients and a considerable saving was made in the labor of adjusting the tachometers. In order to extract so much information from so little evidence, the pattern must be faithfully followed so that all the indications converge to a single conclusion. A single witness can establish only moral certitude of an event but the testimony of a number of independent witnesses agreeing on a fact can make the certainty of the event metaphysical.

So, in using a designed experiment of this kind, we interlock the components as they are found in practice but make it possible to isolate the contribution of each one. Good use was made of this method in controlling the asphalt-treating cycles employed in the manufacturing of transformers.

As shown in Table IV, five stages of the process were examined for a possible saving in time while improving the penetration by the asphalt. Although there are 1,024 possible combinations of these factors, a four-by-four square gave the required information with 16 arrangements. The ultimate measurement to evaluate the process was breakdown voltage. Analysis of the results demonstrated that no appreciable gain resulted from baking more than four hours; no improvement was observed from extending

**Three-by-Three Square Code**

| | I | II | III |
|---|---|---|---|
| A | 1 α | 2 β | 3 γ |
| B | 2 γ | 3 α | 1 β |
| C | 3 β | 1 γ | 2 α |

| | | | |
|---|---|---|---|
| Location | I | II | III |
| | 0.115 | 0.085 | 0.055 |
| Conductivity | A | B | C |
| | 1,600 | 1,800 | 2,000 |
| Coefficient | 1 | 2 | 3 |
| | 0.025 | 0.040 | 0.060 |
| Thickness | α | β | γ |
| | 0.010 | 0.020 | 0.040 |

**Experimental Data**

| | | | |
|---|---|---|---|
| L | +1.603 | +0.369 | −2.507 |
| Mean | +1.655 | −0.066 | −2.784 |
| R | +1.706 | −0.502 | −3.062 |
| L | +2.312 | +0.958 | −1.212 |
| Mean | +1.470 | +1.290 | −0.642 |
| R | +0.627 | +1.622 | −0.0707 |
| L | +2.52 | −0.378 | +2 47 |
| Mean | +2.51 | −0.003 | +2 32 |
| R | +2.50 | +0.372 | +2.17 |

**Test Setup**

| | | | | | | |
|---|---|---|---|---|---|---|
| I | 0.115 | II | 0.085 | III | 0.055 | Location |
| A | 1,600 | A | 1,600 | A | 1,600 | Conductivity |
| 1 | 0.025 | 2 | 0.040 | 3 | 0.060 | Coefficient |
| α | 0.010 | β | 0.020 | γ | 0.040 | Thickness |
| I | 0.115 | II | 0.085 | III | 0.055 | Location |
| B | 1,800 | B | 1,800 | B | 1,800 | Conductivity |
| 2 | 0.040 | 3 | 0.060 | 1 | 0.025 | Coefficient |
| γ | 0.040 | α | 0.010 | β | 0.020 | Thickness |
| I | 0.115 | II | 0.085 | III | 0.055 | Location |
| C | 2,000 | C | 2,000 | C | 2,000 | Conductivity |
| 3 | 0.060 | 1 | 0.025 | 2 | 0.040 | Coefficient |
| β | 0.020 | γ | 0.040 | α | 0.010 | Thickness |

**Figure 4. Tachometer data pattern**

*Three values of compensator-plate location, drag-disk conductivity, co-efficient of conductivity of the disk material, and compensator-plate thickness, each in the critical region, are chosen and coded to a three-by-three square*

Table III. Values of Statistic $F$ and Critical Values for the Tachometer Problem

| Factors | Sum of Squares | Degrees of Freedom | Mean Square | $F$ | Critical (One Per Cent) |
|---|---|---|---|---|---|
| Location | 7.814 | 2 | 3.907 | 11.13 | 8.02 |
| Conductivity | 6.061 | 2 | 3.031 | 8.64 | 8.02 |
| Coefficient | 1.646 | 2 | 0.823 | 2.34 | 8.02 |
| Thickness | 7.226 | 2 | 3.613 | 10.29 | 8.02 |
| All other variables | 3.159 | 9 | 0.351 | | |

Table IV. Asphalt-Treating Cycles

| | | | | |
|---|---|---|---|---|
| Baking time (hours) | 1 | 2 | 4 | 6 |
| Vacuum (minutes) | 2.5 | 5.0 | 7.5 | 10.0 |
| Pressure (minutes) | 2.5 | 5.0 | 10.0 | 15.0 |
| Number of pressure cycles | 1 | 2 | 3 | 4 |
| Release between cycles (minutes) | 1.0 | 2.5 | 5.0 | 10.0 |

the vacuum time beyond the point where the desired absolute pressure was achieved; short-pressure cycles did as much as long ones but there was a steady gain with the number of cycles; finally, no time of rest was required between pressure cycles. As a result of these tests, a very high quality insulation was obtained while the best arrangement of the time cycle permitted 25 per cent more production on the existing facilities.

In these few simple cases advanced here to illustrate the type of problem confronting engineers, the fundamental purpose is to demonstrate the logic rather than the mathematics of significance tests. Our first intention is to measure the uncertainty of inductive conclusions rather than rely on intuitive estimates of the odds. It is important that statistical methods be studied not as a new course in algebra but as a logical approach to physical realities that are essentially unstable within limits. Such realism is sure middle ground between rash assurance and blind idealism. The risks which are involved are unavoidable, and the quantitative expression of them is truly a scientific procedure.

# Electrical Essays

## Network

An electrical engineer finds the two boxes built to Dr. Slepian's specifications as outlined in his December 1948 essay (*p 1141*). The engineer removes the contents of the boxes and installs in each box an air core transformer and one of the resistances he removed from the boxes. The transformers were especially designed for this problem. Subtractive polarity, unity turn ratio, and negligible winding resistance are some of the features of the design. The most important items, however, are the self-inductance of the windings, which is the same for all of them, and the mutual inductance, which is equal to three-fifths the value of the self-inductance. The resistance is added for the purpose of permitting safe testing with direct current, and further masking of the negligible resistance of the windings. The internal connections are shown in Figure 1.

Is it possible to determine by purely electrical measurements at the box terminals which box contains the transformer with series connected windings? What difference, if any, would it make if iron core transformers were used by the engineer?

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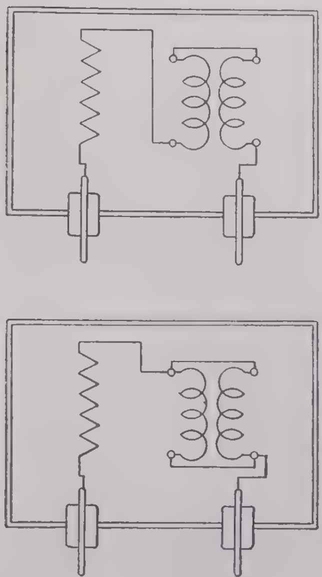


Figure 1

$$M=\frac{3}{5}L$$

## Flux Linkage of an Open Circuit

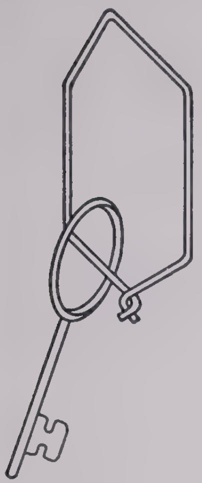
The engineers employed at the company where I work certainly have me confused. The other day I overheard two of them talking about the voltage or electromotive force induced in a turn on a machine by the varying flux linkage of that turn.

Now I think I know what the flux linkage of a *closed* curve or circuit is, but you know, a turn on a machine is not a closed curve or circuit. It may be nearly closed, or it may be part of a larger circuit which is closed, but most always it itself is not closed. Now how can you tell whether a closed tube of magnetic flux links a circuit or not, if that circuit is not closed?

I walked over to the machine where the engineers were talking, and what do you know! It had a wave winding on

it. Now, a turn on a wave winding doesn't come anywhere near closing.

I am not a member of Eta Kappa Nu, not yet anyway, but I like to wear something that reflects my interest in electricity, so I have made myself a key ring shaped like a turn on a machine. But I was smart enough to choose a lap winding, and by twisting together the turn ends, which are already close together, my keys link the ring without any question, and the ring stays linked by the keys, Figure 1. But suppose I had used a wave winding, like in Figure 2. I wouldn't know whether my keys were linked to the key ring or not.



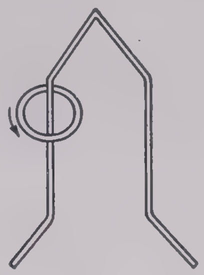


**Figure 1 (left). Alter Ego's key ring**

**Figure 2 (right). Flux linking wave turn**

In Figure 2 I have shown a magnetized ring of iron encircling one side of the wave turn. The engineers would say that the flux of this ring links the turn, because this flux is in exactly the same position as that flux, in the machine, which they said was linking the turn. Now as I slip the magnetized iron ring off the coil side, there must be some place where the magnetic flux will no longer be linking the turn.

*Question 1.* Where does the magnetized ring stop linking the turn?

*Question 2.* As the ring stops linking the turn, so that the flux linkages are reducing to zero, an electromotive force will be induced in the open turn, since the rate of change of the flux linkages will not be zero, isn't that right? True or false?

*J. Slepian, Alter Ego*

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

## Answers to Previous Essays

*Electrostatic or Electromagnetically Induced Electric Field?* The following is the author's answer to a previously published essay of the foregoing title (*EE, Oct '49, p 877*).

"There is but one god, Allah, and Mohammed is his prophet!" There is but one electric field, $\boldsymbol{E}$, (for a particular frame of reference) and Maxwell, our prophet, has proclaimed its properties (in free space) in his eternal equations,

$$\text{div } \boldsymbol{E} = 4\pi\rho \tag{1}$$

$$\text{curl } \boldsymbol{E} = -\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} \tag{2}$$

These equations do not talk of two electric fields, one, $\boldsymbol{E}_s$, an electrostatic field for equation 1 which is concerned with electric charge density $\rho$, and the other, $\boldsymbol{E}_T$, an inductively produced field, in equation 2 which is concerned with varying magnetic flux-density, $\partial \boldsymbol{B}/\partial t$. No, they speak only of a single electric field, $\boldsymbol{E}$, defined uniquely by purely local measurements of force on a probe, and to which *both* equation 1 and 2 apply. There is but one electric field, $\boldsymbol{E}$, and Maxwell is its prophet!

Of course we may arbitrarily, or for our real or imaginary convenience choose to regard the one field, $\boldsymbol{E}$, as made up of an electrostatic part $\boldsymbol{E}_s$, and an inductive part, $\boldsymbol{E}_T$, so that

$$\boldsymbol{E} = \boldsymbol{E}_s + \boldsymbol{E}_T \tag{3}$$

and following our intuition (which may be wrong) that there is some real significance to this resolution of $\boldsymbol{E}$ we may try to find sufficient definitions of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ from their supposedly inherently different properties!

Thus we may believe that $\boldsymbol{E}_s$ arises from charges only, and that $\boldsymbol{E}_T$ arises from changing magnetic fluxes only, so that following Cohn* we define $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ by the following two pairs of equations.

$$\text{div } \boldsymbol{E}_s = 4\pi\rho \tag{4}$$

$$\text{curl } \boldsymbol{E}_s = 0 \tag{5}$$

$$\text{div } \boldsymbol{E}_T = 0 \tag{6}$$

$$\text{curl } \boldsymbol{E}_T = -\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} \tag{7}$$

However, if we confine ourselves and our knowledge of $\rho$ and $\dfrac{\partial \boldsymbol{B}}{\partial t}$ to a limited region in space, such as outside the black box, and in its neighborhood, these equations 4 to 7 are not sufficient to determine $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$. In that region we may make the field all "electrostatic," $\boldsymbol{E}_s$ or all "electromagnetically induced," $\boldsymbol{E}_T$, or quite arbitrary combinations of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$, and still satisfy equations 4 to 7.

Hence, this definition of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ does not permit us to solve the problem of the essay and determine whether the field outside the black box is electrostatic, or electromagnetically induced.

If $\rho$ or $\dfrac{\partial \boldsymbol{B}}{\partial t}$ respectively are known everywhere, so that equations 4 and 5 or 6 and 7 can be applied in our computation throughout all space, and if $\rho$ or $\dfrac{\partial \boldsymbol{B}}{\partial t}$, respectively, are zero beyond some great distance, then $\boldsymbol{E}_s$ or $\boldsymbol{E}_T$ can be determined uniquely, from the defining equations. For example if $\rho$ is known everywhere, then equations 4 and 5 give uniquely

$$\boldsymbol{E}_s = -\text{grad } \psi \tag{8}$$

where

* In my essays, generally I have given no literature references, as compiling such would be burdensome, and since I make no claim to scientific novelties in these essays. However, in this essay I do refer to Cohn (*EE, May '49, pp 441–7*), firstly, because of the very high excellence of the paper, secondly, because its pertinence to the subject of this essay, and thirdly, because it has appeared as recently in *Electrical Engineering*.

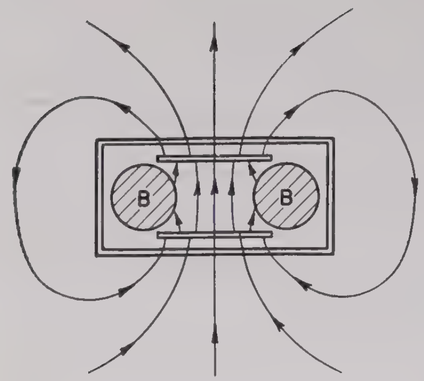



**Figure 1. Fields terminating on charges**

$$\psi = \int\int\int \frac{\rho}{r} dt \quad (9)$$

the integration being taken over all space. And then of course $E_T = E - E_s$.

However, such definition of $E_s$ and $E_T$ is wholly contrary to the meaning and spirit of the electromagnetic field as it appears in Maxwell's theory. The field is defined or determined by purely local measurements, and all that is significant or relevant must be determinable by such local measurements. A resolution of a local field into an electrostatic part and an inductive part which, as in the foregoing, requires a knowledge of the location of all the charges in the universe, must be irrelevant, and without intrinsic physical meaning.

The knowledge of all the charges in the universe required for using equations 8 and 9 must be microscopic as well as extensive. We would need not only to look inside the black box to see what charges are there, but we would have to X-ray the walls of the box, too, to make sure that they do not contain molded within them a metal box or Faraday cage which would isolate the induced field $E_T$ defined by equations 5 to 7 within the black box, leaving the external field to be produced by alternating electrets or otherwise changing charge distributions within the black walls but outside the Faraday cage.

Perhaps some of the questions raised in the foregoing can be appreciated better by looking at Figure 1, in which the black box contains the core $B$ carrying the alternating magnetic flux, as well as the charge bearing plates.

Is what we want of an electrostatic field the property that we can form tubes of force which will spread properly where the field is weak and contract properly where the field is strong, and which will begin and end on the proper amount of charge? Then the field outside the plates in Figure 1 is electrostatic. But so also is the field between the plates inside the box in Figure 1.

Do we also require that the integral of the electric force around any closed path in the field external to the plates be zero? It is! But the same is true for the field between the plates within the box.

Is then the whole field electrostatic? Then why does it vary with $\frac{\partial B}{\partial t}$ in the core?

Another approach to a possible definition of the electrostatic and inductive parts of a field $E_s$ and $E_T$ is through the potentials. As is well known, the electric and magnetic induction fields may be obtained from a scalar potential $\psi$, and a vector potential $A$ through the equations

$$E = -\text{grad}\,\psi - \frac{1}{c}\frac{\partial A}{\partial t} \quad (10)$$

(Cohn,* page 445, equations 42, 43, 44)

$$B = \text{curl}\,A \quad (11)$$

Equation 10 at first sight seems to give us just what we want. It seems to say that thepart of $E$ which depends on $B$ is given by the changing vector potential $A$. We define

$$E_s = -\text{grad}\,\psi \quad (12)$$

$$E_T = -\frac{1}{c}\frac{\partial A}{\partial t} \quad (13)$$

However, with $E$ and $B$ known even everywhere, equations 10 and 11 are not enough to determine $\psi$ and $A$ with any degree of uniqueness. A further relation between $\psi$ and $A$ must be arbitrarily postulated.

Maxwell chose the arbitarary postulate

$$\text{div}\,A = 0 \quad (14)$$

and showed that then under very general conditions equations 10 and 11 lead uniquely to

$$\psi_M = \int\int\int \frac{\rho}{r} dt \quad (15)$$

$$A_M = \int\int\int \frac{i}{r} dt \quad (16)$$

The integrations are taken over all space, and $i$ stands for current density, *including displacement current density*, $\frac{1}{c}\frac{\partial E}{\partial t}$.

Using Maxwell's scalar potential, $\psi_M$, we define $E_{sM} = -\text{grad}\,\psi_M$, which by equation 15 is identical with equation 8 derived from equations 5 to 6 and agrees with Cohn (equation 43).*

Lorentz, on the other hand, chose the arbitrary postulate,

$$\text{div}\,A + \frac{1}{c}\frac{\partial A}{\partial t} = 0 \quad (17)$$

which combined with equations 10, 11, and Maxwell's equations lead to

$$\psi_L = \int\int\int \frac{[\rho]_{(t-r/c)}}{r} dt \quad (18)$$

$$A_L = \int\int\int \frac{[i]_{(t-r/c)}}{r} dt \quad (19)$$

where the integrations again are over all space, and $[i]_{(t-r/c)}$ the "retarded" current density does *not include the displacement current density.*

The Lorentz scalar potential, $\psi_L$, is different from the Maxwell scalar potential $\psi_M$, but it has equally great validity. The "electrostatic" fields defined through these scalar potentials, $E_{sM} = -\text{grad}\,\psi_M$, and $E_{sL} = -\text{grad}\,\psi_L$, will then be different from each other but will have equal justification or validity. This brings out again the point which I am making of the lack of uniqueness and real physical significance or relevance to a resolution of a local electric field into

parts which depend for their definition upon a complete knowledge of all electrical happenings throughout all space.

Radio engineers, who work with wave guides or oscillating cavities make still another arbitrary postulate concerning the relation between $\psi$ and $\boldsymbol{A}$ which is permissible and convenient when the region they are interested in has no space charge density, $\rho$.

It is that

$$\psi_R = 0. \tag{20}$$

For such radio engineers, the electrostatic field, $\boldsymbol{F}_{sR} = -\operatorname{grad} \psi_R$ is zero everywhere and the electric field $\boldsymbol{E}$ which is all within the wave guide or cavity is all-inductive, $\boldsymbol{E}_T = -\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t}$.

Cohn however, who apparently ascribes reality to the resolution of an electric field, and who apparently, (Cohn,* equation 36C) uses the unretarded potentials of Maxwell, in this case would assert that there is an electrostatic field, $\boldsymbol{E}_s$, both inside and outside the wave guide or cavity, and also an induced "(hypothetical)" field $\boldsymbol{E}_T$ (Cohn,* equation 40) which outside the wave guide or cavity is just equal and opposite in direction to the electrostatic field, $\boldsymbol{E}_s$.

There seems then to be no unique and physically significant definition of the electrostatic part of an electric field observed in a limited region of space. I conclude then that the problem of the essay is without physical significance. This then is my solution of the problem.

There is but one electric field, $\boldsymbol{E}$, and Maxwell is its prophet! Great is Allah!

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

*Another Nonlinear Circuit.* The following is the author's solution to a previously published essay of the foregoing title (*EE, Oct '49, pp 877–8*).

The equations of the transformers specified in the essay appear as follows in Heaviside notation:

$$Lpi_1 + Lpi_2 = e_1 \tag{1}$$

$$Lpi_1 + Lpi_2 = e_2 \tag{2}$$

$$Lpi_3 + Lpi_4 = e_3 \tag{3}$$

$$Lpi_3 + Lpi_4 = e_4 \tag{4}$$

When the rectifier is conducting and the terminals of the circuit are open: $i_4 = 0$; $i_3 = -i_2$; and the equations reduce to three:

$$Lpi_1 + Lpi_2 = e_1 \tag{5}$$

$$Lpi_1 + 2Lpi_2 = e_2 - e_3 \tag{6}$$

$$-Lpi_2 = e_4 \tag{7}$$

The impressed voltage is

$$e_1 = E \sin wt = E\left(\frac{pw}{p^2+w^2} - \frac{2p}{w}\right)1 \tag{8}$$

The rectifier drop is

$$e_2 - e_3 = 0 = -E\frac{2p}{w}1 \tag{9}$$

The term $2p/w$ is introduced in both voltage expressions to establish proper fluxes in the cores of the transformrs and thereby to eliminate transient current components.

From equations 5 to 9 inclusive by Heaviside algebra the following expressions and their equivalent trigonometric functions are obtained:

$$i_1 = -\frac{2E}{Lw}\cdot\frac{p^2}{p^2+w^2}1 = -\frac{2E}{Lw}\cos wt \tag{10}$$

$$i_2 = -\frac{E}{L}\cdot\frac{w}{p^2+w^2}1 = \frac{E}{Lw}(\cos wt - 1) \tag{11}$$

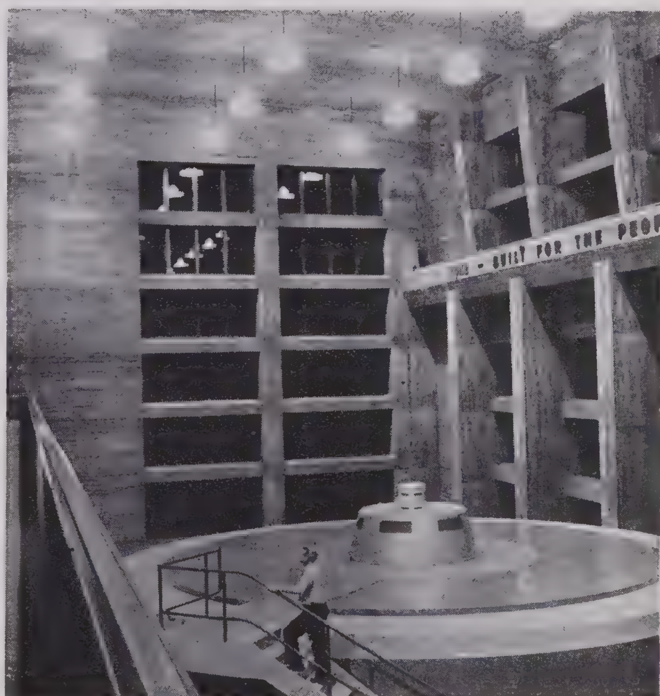
$$e_4 = E\frac{pw}{p^2+w^2}1 = E \sin wt \tag{12}$$

Current $i_2$ undergoes no reversal in the blocking direction of the rectifier and the voltage appearing at the open terminals of the circuit is the impressed voltage $E \sin wt$.

A. A. KRONEBERG (F '48)

(Southern California Edison Company, Los Angeles, Calif.)

## Plexiglas Rings Diffuse Light



In the generator room (shown above) of the Tennessee Valley Authority's Fontana Dam, problems of glare and uneven illumination are solved with the use of Plexiglas rings. Five inches high, with a 15-inch-diameter opening and an over-all diameter of 40 inches, these white translucent rings are attached to the lamps on the ceiling, which consist of 30 Holophane Company high-bay reflectors of prismatic glass, each using a 750-watt clear incandescent bulb. Intensity of illumination at floor level is 12 foot-candles with the lights at a height of 54 feet. The rings shield the bulbs from direct view at normal viewing angles. Plasti-Line, Inc., of Knoxville, Tenn., fabricated the rings, and the plastic is a product of Rohm and Haas, Philadelphia, Pa.

# Self-Saturation in Magnetic Amplifiers

W. J. DORNHOEFER

ASSOCIATE AIEE

SATURABLE reactors, in their simpler forms, have been used in controlling many types of equipment. As is known, control is effected by adjustment of the reactor impedance with d-c premagnetization. The a-c windings are so connected that no fundamental component of power-frequency voltage appears in the d-c control winding. For optimum utilization of the core structure, the control winding must supply premagnetization equal to the sum of the magnetomotive force of the a-c windings and the magnetomotive force necessary to saturate the core. Generally, the control winding consists of many turns of fine wire. As a result, a high voltage can be induced in the control winding if one a-c coil becomes inoperative and the effective inductance and time delay of the control circuit are substantial. However, these factors can be reduced if feedback is used to equilibrate the magnetomotive force of the a-c windings so that the control winding need supply only the magnetomotive force required to saturate the core. Consequently, saturable reactors with feedback, or magnetic amplifiers, have been applied in many cases where simple saturable reactors would have been unsuitable.

Feedback can be accomplished by rectifying the alternating current flowing in the main windings and causing the resulting direct current to flow in additional turns on the reactor. This is termed external feedback. A second type of feedback, known as self-saturation, employs an electric valve in series with each a-c (anode) winding. Ideally, in this circuit, the current in the anode winding itself is pulsating and unidirectional, as is the magnetomotive force. Control is effected during the nonconducting alternation, in the presence of zero anode-winding magnetomotive force. Magnetic amplifiers employing external feedback and those using self-saturation give similar performance.

However, the self-saturating circuit is superior for these two reasons:

1. For the same output, a magnetic amplifier using external feedback requires 25 to 50 per cent more core material and approximately 100 per cent more copper than that required by the self-saturating type.

2. In the circuit employing external feedback, the coupling between the feedback winding and the anode winding determines the effectiveness of the feedback. This is not a factor in the self-saturating circuit.

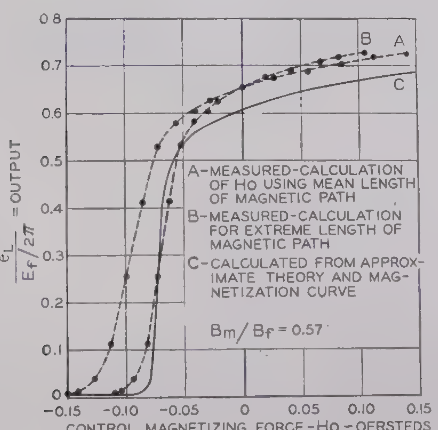



**Figure 1. Calculated and measured average output voltage of a half-wave magnetic amplifier circuit as a function of control magnetizing force with the radial depth of the core taken into consideration**

Self-saturating magnetic amplifiers have been evolved for both a-c and d-c output and for single-, 3-, and 6-phase supplies. The polyphase connections are generally used to obtain fast response and minimize output ripple.

An analysis of a reactor with self-saturation shows that the output voltage wave resembles that of a gas-filled grid-controlled electronic tube. As with such a tube, the portion of the voltage wave associated with the "firing" of the device has a very great slope. The time of firing (or the firing angle) and the resultant output voltage depend on the working flux density ($B_m$), the initial flux density ($B_0$), and the critical flux density ($B_f$) at which firing occurs. In particular, for a given working flux density and critical flux density, the firing angle depends on the initial flux density associated with the magnetomotive force of the control winding at the moment the supply voltage crosses the axis with positive slope. Thus, as the control flux density is increased, the firing angle becomes smaller and the output voltage has higher peak and average values. Control can be effected by any of the following means, singly or in combinations: continuous direct current; amplitude or phase of synchronous alternating current; amplitude of asynchronous alternating current; synchronous pulses; and adjustment of anode current during negative alternation by adjustable-impedance elements in shunt with the anode winding or rectifier.

Analysis shows fair agreement with results obtained in the laboratory (see Figure 1). Sources of error include: eddy current shielding in the laminated core structure and consequent broadening of the hysteresis loop; and effect of distributed parameters in the magnetic circuit, particularly the assumption of a mean length of magnetic path.

The characteristics of the rectifiers used are very important in determining the control characteristics of an amplifier. Any reverse, or leakage, current in the anode windings causes demagnetizing forces in the core which the control winding must overcome. As an example, one per cent leakage current in the anode winding of a reactor with a core of high-permeability gapless laminations can cause a demagnetizing force of the order of ten times that required for control. Obviously, rectifiers with high inverse resistance are needed for magnetic amplifier circuits, particularly where high permeability gapless cores are used.

Digest of paper **49-140**, "Self-Saturation in Magnetic Amplifiers," recommended by the AIEE Electronics and Basic Sciences Committees and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Inherent-Overheating Protection

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INHERENT-OVERHEATING protection is, as the name implies, protection based upon the actual motor temperature; thus, the motor is protected on the basis of total temperature and not temperature rise, as is the case when an external current-limiting device is used. Fundamentally, in order to realize true inherent-overheating protection, the temperature of the thermal element should follow at all times the motor-winding temperature, thus limiting the winding to a definite temperature, regardless of conditions of line voltage, motor load, ambient temperature, or ventilation. A common location for the thermostat is in the motor end shield, where it is in as close heat-receiving relationship to the stator windings as practicable. An auxiliary heater is provided in the thermostat to compensate for the difference in temperature between the stator copper and the thermostat mounting and to provide fast tripping under locked-rotor conditions. The auxiliary heater maintains the disk at a temperature somewhat above its ambient temperature; thus, the tripping characteristics of the disk-type thermostat are affected in a predetermined way by the ambient temperature of the thermal element.

The temperature rise of the disk above its ambient temperature is, of course, proportional to the watts generated in the thermostat, that is, to the $I^2R$ losses. Hence, it is clear that the rise of the disk must be proportional to the square of the current, since the resistance of a nichrome heater is practically constant. Reduced to mathematical terms, the foregoing statement becomes

$$T_d - T_a = K_t I_u^2 \qquad (1)$$

where

$T_d$ = Disk-opening temperature
$T_a$ = Ultimate tripping ambient temperature at current $I_u$
$I_u$ = Ultimate tripping current at ambient $T_a$
$K_t$ = Proportionality constant

This equation shows how the ultimate tripping amperes is affected by disk-opening temperature as well as by ambient temperature.

The problem of proper thermostat selection now evolves itself into one of determining which combination of thermostat design features will allow the temperature rise of the disk above the end shield to follow the rise of the motor winding above the end shield. In a normal motor, the temperature rise of the winding end extensions above the end shield is very nearly proportional to stator copper loss, which is in turn directly proportional to the square of the stator current. The equation for the temperature rise is

$$T_w - T_a = K_m I^2 \qquad (2)$$

where

$T_w$ = Winding temperature
$K_m$ = Proportionality constant
$I$ = Stator current under load

The similarity between equations 1 and 2 easily can be noted. With this similarity in mind, and with the knowledge that the motor and thermostat are connected in series, it readily can be seen that $I_u = I$ and $T_a$ in both equations are the same. It then follows that if $K_m$ equals $K_t$, then $T_d$ equals $T_w$ for all values of $I$. That is, the disk temperature is the same as the winding temperature at all loads. All that remains then is to set the disk to open at the desired maximum winding temperature. In other words, the steps in selecting the proper thermostat for ideal protection are

1. Determine $K_m$ by test on the motor.
2. Select a thermostat having a $K_t$ equal to the tested value of $K_m$.
3. Use a thermostat with a disk-opening temperature equal to the maximum desired temperature of the winding.

The exact procedure just outlined is rather unwieldy because, in applying a thermostat, it would be necessary to take a test on each motor to determine the value of $K_m$. In practice, this procedure is simplified by resolving $K_m$ into two components. Let $W_m$ equal total watts copper loss in the main winding per degree rise of winding temperature above end-shield temperature. Let $r_1$ equal resistance of main winding. Then equation 2 becomes

$$T_w - T_a = (r_1/W_m) I^2 \qquad (3)$$

Now, in contrast with $K_m$, $W_m$ will remain constant for a number of windings of varying resistance; it is primarily dependent upon the physical size of the motor, with which it can be correlated.

For ideal protection, that is, for the temperature of the disk to follow the temperature of the winding at all currents, it is necessary that

$$r_1/W_m = K_t = (T_d - T_a)/I_u^2 \qquad (4)$$

When equation 4 is satisfied, the temperature of the disk follows that of the winding at all currents and ideal protection is obtained. Since the disk always opens at the same temperature, the winding is always protected to the same total temperature. While equation 4 expresses the conditions for ideal protection, practical use of it in this particular form is not quite so easy because values of $K_t$ ordinarily are not published. However, equation 4 reduces to a more usable form, as the disk-opening temperature and the ultimate tripping currents at different ambient temperatures usually are available.

Digest of paper **49-71**, "Fundamental Theory of Inherent-Overheating Protection Under Running Overload Conditions," recommended by the AIEE Rotating Machinery Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Range-Adjusting Radiosonde Recorder

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A RADIOSONDE is the air-borne unit of an air-to-ground telemetering system. This equipment transmits audio frequencies in time sequence, which represent temperature and humidity, and a fixed reference signal, covering a range from 8 to about 200 cycles per second.

Air-borne radiosonde equipment, being of necessity lightweight, expendable, battery-operated, and subject to wide variations of temperature, pressure, and humidity during balloon ascent, is subject to certain calibration drifts, exclusive of changes in primary measuring elements. The reference frequency, transmitted periodically between indications of temperature and humidity, indicates the magnitude and direction of such drifts. This reference frequency drifts in the same proportion as the drifts occurring in the other indications.

Under a development contract between the Signal Corps Engineering Laboratories, Belmar, N. J., and the Leeds and Northrup Company, a recorder has been developed which performs automatically the functions of range-adjustment and calibration.

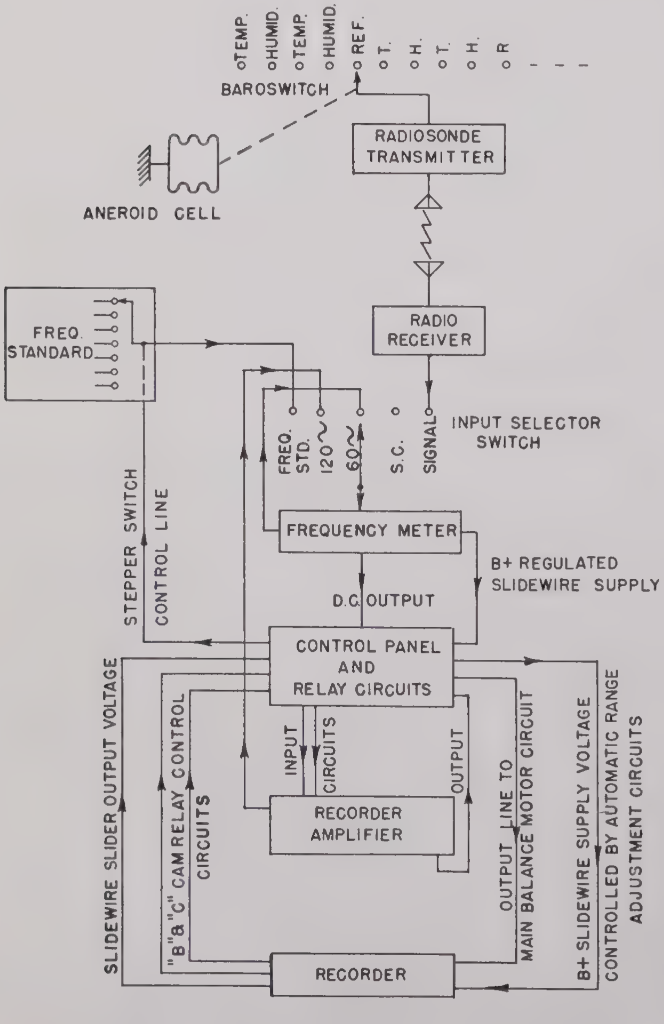


**Figure 1. Block diagram of complete system**

This radiosonde recorder includes: a 10-inch strip chart covering the ranges 0 to 200 cycles per second; a frequency meter which converts incoming frequency, over the range from 8 to 200 cycles, to direct current proportional to frequency in a linear fashion; a frequency standard with a limit-of-error of 0.01 per cent, or better, for automatic calibration and linearity checks; and a control panel having circuits for automatic range adjustment of the recorder in accordance with the reference-frequency signals received. Drifts occurring in the air-borne transmitter are cancelled out by this range adjustment, resulting in corrected indications for temperature and humidity. An over-all limit-of-error of $\pm$ 0.25 per cent, or better, is obtained, including the automatic range-adjustment feature, the operation of frequency meter circuits, and automatic relay switching at the control panel.

The complete recorder is shown in Figure 1. The signal from the radiosonde transmitter is received by a radio receiver with its output circuit connected to the input circuit of the frequency meter. The corresponding direct voltages produced by the frequency meter then cause the recorder to indicate these values on the chart. No signals above approximately 175 cycles are produced for any temperature or humidity condition. On the other hand, all reference signals utilized for range adjustment of the recorder occur above 175 cycles. A recorder control cam (*B* cam) closes a relay circuit any time the recorder balances above nominal 175 cycles, thus recognizing the presence of a reference signal. This activates the automatic range-adjustment circuits, causing the recorder to readjust its range. All reference signals are made to indicate 190 cycles on the chart by varying the slide-wire voltage until the direct current corresponding to the incoming signal and a tap point on the slidewire representing 190 cycles (95 per cent of full scale) are of equal value. This is the corrected reference-point indication, resulting in corrected humidity and temperature indications. The 190-cycle value is used since this is the nominal value of the reference signal.

Ease of service and maintenance, compactness, and convenience are secondary, but important, features. All units are designed for standard 19-inch relay rack mounting, each unit sliding into place in the rack and making connections automatically to the rack circuits as it is fastened in place through the use of multiple-contact connectors. In some cases, as many as 60 connections are made when a unit is plugged in. A-c and d-c power and measuring circuits of various levels are carried in these connectors.

Digest of paper 49-152, "Automatic Range-Adjusting Radiosonde Recorder," recommended by the AIEE Instruments and Measurements Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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# Increased Power Supply for Northern Illinois

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FELLOW AIEE

**In northern Illinois, four interconnected electrical utility systems have embarked on a postwar construction program to augment their collective generating capacity. When the project is completed they will be able to supply 3,000,000 kw of power. Equipment additions will cost $428,000,000, one-half of this estimated expense going for distribution facilities.**

PROVIDING additional capacity to supply increasing electric power demands has been a difficult problem during the last few years for nearly all utilities. This is a condition to be expected in an industry such as this, in which roughly four dollars of capital investment must be made for every dollar of additional revenue. Plans must be made far in advance, because three to four years must elapse after a large generating unit is decided upon before it is ready for service. The majority of utilities are just beginning to restore capacity to normal standards after the effects of the material shortages during and just after the war.

This article outlines the methods by which one integrated group of utilities plans for future growth. A few of the more interesting construction projects are also described. The program explained here includes problems that are, in general, characteristic of all utilities, although local conditions may vary to a large extent in different parts of the country.

## INTERCOMPANY PLANNING

The group of companies supplying electric power to Chicago and most of northern Illinois consists of the Commonwealth Edison Company, the Public Service Company of Northern Illinois, the Illinois Northern Utilities Company, and the Western United Gas and Electric Company.

The territory served by these utilities, as shown by the map (Figure 1), has an area of about 11,000 square miles in which live about four per cent of the country's population. It covers much of the northern portion of Illinois, extending from Lake Michigan to the Mississippi River. The territory is quite diversified, ranging from the densely populated city of Chicago, served by the Commonwealth Edison Company, to the sparsely settled territory, served by the Illinois Northern Utilities Company. Each company operates independently and provides its own local transmission and distribution facilities, with a certain amount of co-ordination of practices and interchange of information. This has been found to be an efficient and economical procedure.

Provision for additional generating capacity is a different matter. For greater over-all economy, the generating stations of the four companies are all interconnected, and by this means the group of generating stations is operated with the same efficiency as though operated by a single company. Operating as an interconnected system, large generating units of 100,000- to 150,000-kw capacity may be used with substantial savings in cost per kilowatt of capacity and production cost. The total necessary reserve is much less than with each company operating independently, and in the hour-to-hour operation of the system, use is made of the most efficient turbogenerators for the combined group of four companies.

Planning for additional generating capacity and for the associated major transmission lines of this group of companies is an intercompany problem. Handling it on a co-operative basis not only provides for the interest of all companies equally, but also affords broader judgment in determining future load estimates on which the need for capacity is based.

An Intercompany Committee on Load Estimates makes and revises at frequent intervals an estimate of the maximum demands for a 5-year period. When the estimates of this committee indicate that new capacity is necessary to maintain a safe operating reserve within the next four years (and they usually do), a Committee on Load and Capacity studies the various alternative sites in the territory of the four companies where this capacity might be installed and estimates the relative power cost at each site, including transmission lines to the zones of estimated capacity deficiency.

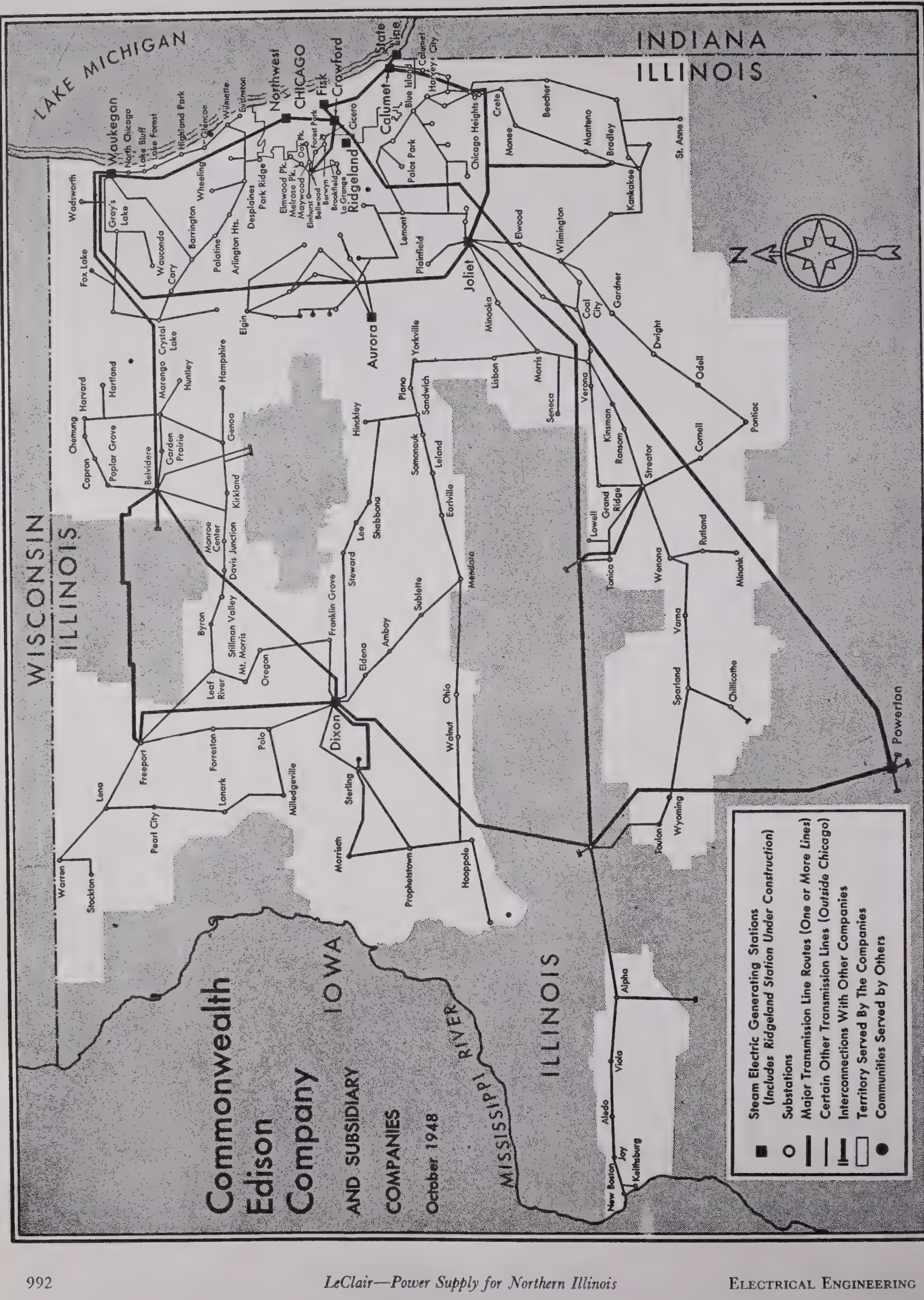
Using these estimates as a basis, a Power Supply Committee prepares a recommendation to the Chairman of the Companies on the size, location, and service date of the necessary generating project. These men have had considerable experience in all fields of the utility business, and reliance is based on their judgment in the final analysis. A new generating unit, when installed, is available to all companies and the power costs are equitably adjusted through an Intercompany Service Agreement. Additional agreements are also available with other utilities outside this group, through which reserve capacity is interchanged in emergency.

## EXPANSION PROGRAM

Just prior to the termination of the war, it was the consensus of both industrial leaders and government officials that business would drop for a few years after the war. So

Essentially full text of a paper presented before the Midwest Power Conference, April 18–20, 1949, Chicago, Ill.

**Titus G. LeClair** is Assistant Chief Electrical Engineer, Commonwealth Edison Company, Chicago, Ill.


Commonwealth Edison Company
AND SUBSIDIARY COMPANIES
October 1948
LAKE MICHIGAN
WISCONSIN
ILLINOIS
INDIANA
ILLINOIS
IOWA
ILLINOIS
MISSISSIPPI RIVER
CHICAGO
State Line
Calumet
Fisk
Crawford
Northwest
Ridgeland
Waukegan
Joliet
Aurora
Dixon
Powerton
Steam Electric Generating Stations (Includes Ridgeland Station Under Construction)
Substations
Major Transmission Line Routes (One or More Lines)
Certain Other Transmission Lines (Outside Chicago)
Interconnections With Other Companies
Territory Served By The Companies
Communities Served by Others

far as the utility business was concerned, the drop was of very short duration, and there was no opportunity to build up the reserve which was so severely depleted during the war before the postwar load growth began. In 1945, the first peak load of this group of companies after the end of hostilities was 34,000 kw greater than the highest wartime peak.

Owing to restrictions imposed during the war on the construction of facilities and to the unprecedented growth in load during and since the war, the reserve electric generating capacity of the companies has been absorbed. Distribution facilities have been heavily loaded. To correct these deficiencies in reserve capacity, which accumulated during the war years, and to provide additional facilities for the steadily increasing demand, a major expansion plan was started as soon as restrictions were removed. Although this program was delayed by shortages of labor, materials and equipment, the companies have expended for gross plant additions, including some additional gas facilities outside of Chicago, an amount in excess of $188,000,000 during the three postwar years ending December 31, 1948. Nearly half of this amount, or an investment in excess of $90,000,000 was expended in 1948 alone.

Figure 2 shows the load growth in this territory since 1939. In 1948, the load was 2,423,000 kw, or 418,000 kw above the wartime peak of 1944.

To meet the large future increase in load, the Commonwealth Edison Company and subsidiary companies are now engaged in the largest generating station construction program in their history. Since the end of the war, three new generating units totaling 307,000 kw have been placed in service, and four additional units with a total capacity of 517,000 kw in various stages of construction bring the postwar program, to date, to a total of 824,000 kw. This capacity is urgently needed, and although every effort is being made to complete the program as fast as is physically possible, the last unit in the program is not scheduled for service until 1952, at which time the system reserve is expected to be re-established at a normal level.

The postwar generator program of the Edison Group of Companies is shown by Figure 3. In December 1945, a 50,000-kw unit was placed in service in the Dixon Station of the Illinois Northern Utilities Company. In September 1947, a 107,000-kw unit was placed in service at the Calumet Station in Chicago. In June 1949, a 150,000-kw unit was placed in service at Fisk Station in Chicago.

Well over half of the load of this group of companies is concentrated within the city of Chicago and this involves a major problem in obtaining cooling water for condensing purposes at steam generating stations. The lake front area is reserved for recreational purposes and is not available for any industrial plant, leaving the Chicago and Calumet Rivers, and the Chicago Sanitary and Ship Canal as the only sources of cooling water. Cooling water in these channels is also restricted by the federal limitation on the diversion of water from Lake Michigan into the Chicago and Calumet Rivers. Therefore, the location of generating stations on these rivers and their capacity requires careful engineering planning and study. Such studies resulted in the purchase of an additional generating-station site approximately three miles downstream from Crawford Station on the north bank of the Chicago Sanitary and Ship Canal. The new station, known as Ridgeland, is now being developed. The present plans call for an ultimate capacity of about 600,000 kw. Initially, two 150,000-kw units will be installed, the first scheduled for completion in 1950 and the second in 1951.

**Figure 1 (opposite page). Map of the Commonwealth Edison system in Northern Illinois**

The remainder of the program consists of two units in stations of the Public Service Company of Northern Illinois; a 107,000-kw unit at its Joliet Station will be placed in service early in 1950, and a 110,000-kw unit at its Waukegan Station is scheduled for service in 1952. With the completion of this program, the total net dependable generating capacity on the interconnected system will be about 3,000,000 kw.

The new generating station at Ridgeland will incorporate the most recent developments in boiler and turbogenerator design. Each unit will consist of a high-pressure 3,600-rpm turbine with a 50,000-kw generator and a low-pressure 1,800-rpm turbine with a 100,000-kw generator. The high-pressure turbine will be designed for a throttle steam pressure of 1,800 pounds per square inch, 1,050 degrees Fahrenheit, and will exhaust directly into the low-pressure turbine at a steam pressure of about 434 pounds per square inch.

There will be two boilers per unit, each with a capacity of 730,000 pounds of steam per hour. The boilers will be equipped with cyclone burners of the same basic design developed in Edison's Calumet Station.[1] The station is expected to deliver one net kilowatt-hour to the system for about one pound of Illinois coal. One unusual feature in the design of the station, which is a modern development, will be the use of centralized control for the entire station. The control room will be located in the center of the 4-unit station between the boiler and turbine rooms, and from this location, the operators will be able to operate the boilers,

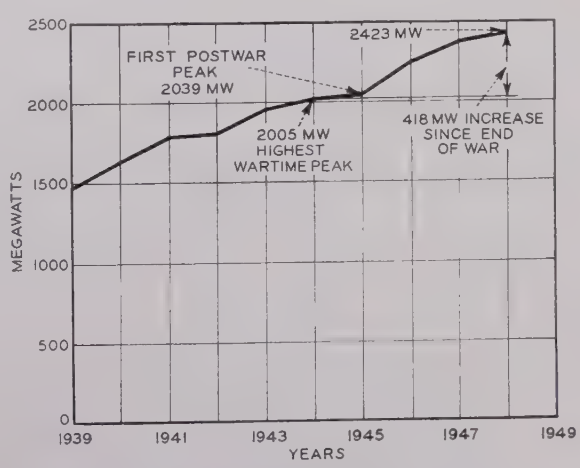



**Figure 2. Coincident maximum demand of Commonwealth Edison Company and subsidiary companies during the 9-year period, 1939 to 1948**

turbogenerators, as well as the high-voltage transmission terminal.

## COAL HANDLING

In addition to increasing system generating capacity, it was necessary to make some major revisions in coal-handling facilities, both at the bulk supply point and at the stations. Practically all of the coal burned in the four Chicago stations is delivered by barge from Havana, Ill., located on the Illinois River about 200 miles southwest of Chicago. Coal is delivered to Havana by a 75-mile rail haul from the central Illinois coal fields. The present transfer plant built in 1937 does not have sufficient capacity to meet present-day requirements for barged coal. The new transfer plant, scheduled for completion this year, will transfer about 15,000 tons of coal from rail to barges in an 8-hour day. This is about 1,000,000 tons per year more than the present plant can handle, operating on a 20-hour day. It will take care of all barged coal requirements of the combined companies for some time in the future.

Fisk Station, where the new 150,000-kw unit was put into service this year, is an old station in a congested area and does not have sufficient coal storage space on the station property. The storage yard is about one-third of a mile downstream from the station. Until this summer, coal removed from storage for use at Fisk traveled the short distance by barge or by rail.

Both barge and rail hauling are subject to traffic tie-ups. For continuous reliable supply of coal from storage, a belt conveyor system has just been completed which takes coal directly from the yard to the station bunkers. The conveyor is loaded from the crane system at the storage yard site.

It goes under one public street and then travels above the surface, sloping upward to the top of the station, 115 feet above ground level. The belt has a capacity of 800 tons per hour and will easily supply present and future coal requirements for the 450,000-kw station.

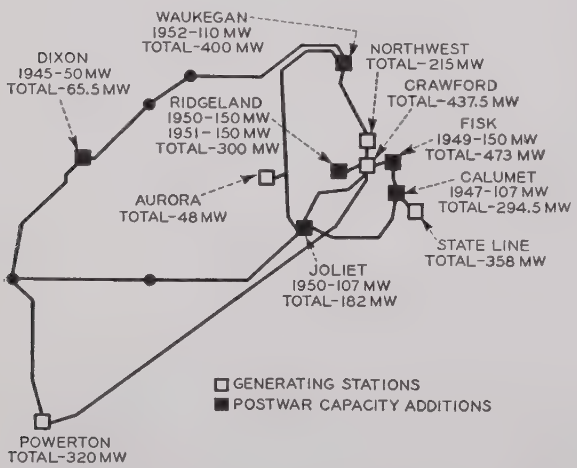



**Figure 3. Commonwealth Edison Company and subsidiary electric power companies generating stations and interconnected system**

## STATION INTERCONNECTIONS

The bulk power transmission system requires fewer capacity additions and changes than the stations which this system interconnects. The largest item will be the two 66-kv 140,000-kva lines which are underground cable from the new Ridgeland Station to Crawford Station. These lines will be single-conductor oil-filled cable, similar to, but somewhat larger than cables previously installed. A new 132-kv overhead transmission connection was established in July 1949 between Joliet and Crawford Stations in conjunction with the new Joliet unit and a new 132-kv substation in the Public Service territory at McCook.

## DISTRIBUTION FACILITIES

The postwar expansion program for the distribution plant will extend through 1952. Dollarwise, about half of the total estimated expenditures for the electric plant will be for distribution facilities. With a rapidly increasing load and a small margin of reserve in the distribution plant, it was necessary to revaluate some of our past principles of system planning.

One of the first steps along this line that offered promise of immediate relief was the rerating of substation transformers and associated equipment on a thermal basis to obtain the maximum load-carrying capability.[2] The study revealed that many substation transformers could carry loads ranging from 125 to 185 per cent of name plate ratings in emergencies.

In a majority of cases, this increased load-carrying capability was gained without any physical changes. It was necessary, in some instances, to reinforce some of the associated equipment, such as cable connections to the busses, disconnects, and current transformers.

## 66-KV SUBSTATIONS

The amount of reserve in the 12-kv subtransmission system from generating and distributing stations to substations in the city was also critically low. Meeting the need for this increase in subtransmission capacity, in accordance with previous planning concepts, would have added a large number of new 12-kv underground cables and extended practically all of our generating and distributing station switchhouses. The solution was found in a simplified type of 66- to 12-kv substation, ranging in capacity from 70,000 to 100,000 kva, to serve as sources of 12-kv supply to the 12- to 4-kv distribution substations. One of these substations was placed in service in Chicago in December 1948, one in June 1949, and four additional ones are scheduled for service within the next three years.[3]

## SMALLER SUBSTATIONS

The increase in existing distribution substation capacity obtained by rerating on a thermal basis helped to carry the increasing load until new facilities would be delivered and installed. Where practical, additional transformer and 4-kv feeder capacity was installed in existing substations, but a considerable number of new substations had to be planned throughout the territory of the four companies. These new substations vary from 1,500-kva units or primary network type of installations, suitable for the lower-density out-

lying territory, to 22,500-kva installations in the more densely loaded metropolitan area. In all of these substations, simplified designs are being utilized to the maximum possible extent, and factory-assembled gear is being installed in order to expedite the work. As a step in reducing costs, without jeopardizing quality of service, bus regulation is being used in Chicago instead of individual feeder regulation when system requirements permit. In some cases, 12-kv cables are connected directly to transformers to eliminate switching equipment.

## SUPERVISORY CONTROL

With the expansion of the system to keep pace with the increasing loads, it was highly desirable to augment the facilities that provide effective means of operating and controlling the enlarged system. A typical example of this type of project is the new substation supervisory control system now in operation in Chicago.[4] The city has been divided into four control areas, with a control center in each area. When the project is completed, all substations in each area, except those having rotating equipment, will be controlled from its center. Each center serves as headquarters for the traveling operators of the area, and thus effects close co-ordination between supervisory control and operation.

## DISTRIBUTION LINES

The distribution lines, since the end of the war, have been expanded considerably, and there is still a sizable program ahead for the next five years. The expansion in building of homes, stores, and factories has added a large number of new customers, with many of them located in what heretofore was undeveloped territory, and, therefore, requiring complete extensions of electrical facilities. The companies outside of Chicago have been quite active in developing the farm load, and today electricity is available to more than 98 per cent of the farms and rural units in the territory served by the four companies. In 1925, there were about 1,000 farm customers; but today, there are over 46,000 farm customers using an average of about 3,700 kilowatt-hours per year. Just keeping up with the increase in the load of existing customers would have been quite a job in itself, and the addition of new customers has made the task considerably greater.

A big help in providing for the increased loads has been a capacitor program. The four companies have installed about 200,000 kva of capacitors since 1945, and the program will be continued to assure the most efficient use of the distribution plant. These capacitors, by improving power factor, have made possible the carrying of a substantial additional load on present distribution lines.

On the overhead distribution system, about 385,000 kva in transformers has been added since 1945, and the transformer requirements for the next five years are expected to continue at a fairly high level.

Commonwealth Edison has been confronted, in this postwar period, with another problem peculiar to its own distribution system, which has added considerably to the complexity of its expansion program. The company had adopted the policy of reducing, over a period of years, the areas in which direct current was supplied, and of substituting 60-cycle alternating current. By the end of 1941, this area had been reduced until it was restricted to the Loop and immediate adjoining area. During the war this changeover program, of necessity, was virtually discontinued. In the postwar period, the remaining d-c load began to grow at a startlingly fast rate, and since it was highly desirable to get as much of this increase onto the 60-cycle system as possible, Commonwealth Edison has undertaken to accelerate its conversion program.

## CONCLUSION

The rapid growth of industry has given all companies in the electric power field a very heavy burden of new construction to meet increasing demands. Pending the completion of this construction, they have been faced with shortages of capacity resulting from wartime restriction which have made necessary carrying these demands with less than normal margin of reserve. They have also been confronted with higher construction costs. The associated companies in the northern Illinois territory have been no exception to this national trend.

With the present high costs for new utility equipment all standards and practices had to be challenged, and the advantages that they offered in reliability and flexibility of operation had to be revaluated in relation to the higher costs.

It has been a real challenge to engineers to get more value out of the dollar, to obtain the lowest possible costs compatible with high-quality service. All elements of the electric plant are being used to the highest possible value of loading capability that can be economically justified. Full advantage is being taken of technological improvements in equipment which permit increased economy in system planning and in station and line design.

The construction program projected for the period 1949–52 includes provision for the restoration of reserve capacity and for substantial expansion of all elements of the electric plant to supply the increased loads in the territory of the four companies. The total program of the plant expansion, including some facilities for the gas plant and for the general plant, is estimated to require $340,000,000 in gross additions to the system plus the $188,000,000 already spent since the end of 1945.

Providing electrical utility service is a continuing and challenging engineering problem which requires the co-operative efforts of many men. The communities in this territory are growing at a healthy rate and the electrical utilities fully recognize their responsibility to provide additional facilities for the electrical service which is so vitally necessary to our homes and the operation of industry and commerce.

## REFERENCES

1. The Horizontal Cyclone Burner, **A. E. Grunert, L. Skog, L. S. Wilcoxson.** *Transactions*, American Society of Mechanical Engineers (New York, N. Y.) 1947, page 613.

2. Economic Loading of a Transformer System, **D. L. Levine, H. E. Smith.** AIEE *Transactions*, volume 68, 1949, pages 733–39 (*Proceedings* T9188).

3. A 66-Kv Subtransmission Plan for a Metropolitan Area, **K. M. Smith, E. L. Michelson.** AIEE *Transactions*, volume 68, 1949 (*Proceedings* T9172).

4. Four Remote Control Centers Supervise 46 Substations, **T. G. LeClair.** *Electrical World* (New York, N. Y.), August 16, 1947, page 78.

# German Missile Accelerometers

THOMAS M. MOORE

SINCE PUBLICATION of "V-2 Range Control Technique,"[1] further lifting of military restrictions has made more information available about the techniques employed to guide the German *A-4* (*V-2*) and *A-4b* rockets to a predetermined target. These techniques will be reviewed in this article.

**Range control accurate to one mile in 200 and lateral guidance accurate to three yards in 20 miles were achieved with German-developed V-2 rockets by using electric, mechanical, and electrochemical devices. This article reviews declassified information on the single-, double-, and triple-integrating accelerometers which were mounted on stabilized platforms in the rockets for this purpose.**

An *A-4* (*V-2*) rocket which has been preset for a long range trajectory rises vertically for the first four seconds. The longitudinal axis then is deflected gradually toward the target to a final angle of approximately 47 degrees from horizontal after approximately 60 seconds of propulsion. The tilting program is obtained through signals from a motor controlling the precession of the pitch gyroscope at rates which vary from 1.8 degrees per second shortly after take-off to 0.5 degree per second in the region of maximum velocity. Aerodynamic steering is effected during the propulsion period by graphite vanes in the jet stream and by air vanes. At fuel cutoff the air vanes are locked in a neutral position, and the missile follows a free ballistic trajectory to its target. Control of range is accomplished by a 2-stage reduction in thrust (from 25.7 tons thrust to 8 tons thrust to cutoff) when the missile has attained velocity sufficient to carry it to the target. In the process of fuel cutoff a number of considerations such as time dispersion involved in closing relays, valves, and so forth, become important. It was advantageous for this and other reasons to provide fuel cutoff in two steps.

## RANGE CONTROL

Devising means for accurately controlling the range of the *A-4* reportedly comprised a major effort of the *A-4* designers. The problem consisted of accurately controlling velocity and space position of a 12-ton projectile under a thrust of 26 tons at a velocity nearly twice that of a rifle bullet. At first a radio Doppler system was employed for range control and a guide-beam system was used for azimuth control. But, for operational use, these systems were at least partially discarded because of their complexity and susceptibility to jamming. A Doppler system, however, is extremely useful for experimental purposes, especially when a third station is added. Position and velocity in space then may be determined with a high degree of accuracy.

A second method of providing accurate timing of combustion cutoff and of measuring the lateral deviation from a prescribed course is accomplished through use of integrating accelerometers mounted in the missile. Such devices have the advantage that no ground stations are necessary. They are light in weight and, above all, are free from jamming.

## MUELLER MECHANICAL INTEGRATING ACCELEROMETER

The earliest mechanism used for range control was a simple timing device preset to shut off the fuel supply after a burning time sufficient to attain the velocity required for the missile to reach its target. The advantage lies mostly in its simplicity, since the system does not compensate for unanticipated deviations in thrust. This device is based upon the fact that cutoff velocity is the most important parameter in determining range of the missile. For small deviations in space position and in elevation angle, the range attained varies approximately as the square of the velocity. Early German investigations aimed at developing a device to provide a cutoff of the rocket fuel accurate to within one part in 1,000 of the desired cutoff velocity. From a large number of proposals and test devices, four actually were used. A study of the *A-4* trajectories will show that a velocity dispersion of 4.5 feet per second at combustion cutoff will result in a 0.4-mile dispersion in range. Figure 1 shows a typical trajectory.

The first and least accurate of the integrating accelerometer units which were flight-tested was the rate gyroscope device shown in Figure 2. The enclosed gyroscope is mounted in such a way as to precess at a rate determined by the acceleration of gravity before take-off, and at a rate determined by the superimposed forces of gravity and missile acceleration after take-off. The angle through which the gyroscope precesses is a measure of the integrated

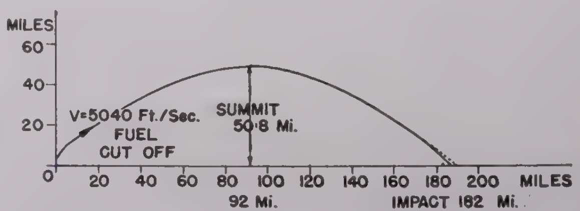



**Figure 1. *A-4* trajectory**

**Thomas M. Moore** is Consultant to United States Army Ordnance, Fort Bliss, Tex.

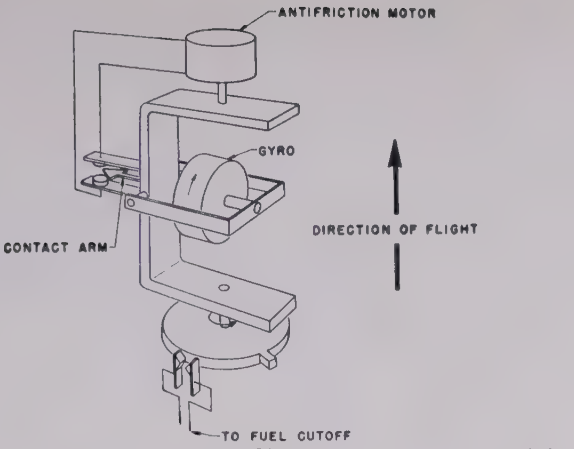



Diagram from North American Aviation

**Figure 2. Diagram of the Mueller integrating accelerometer**

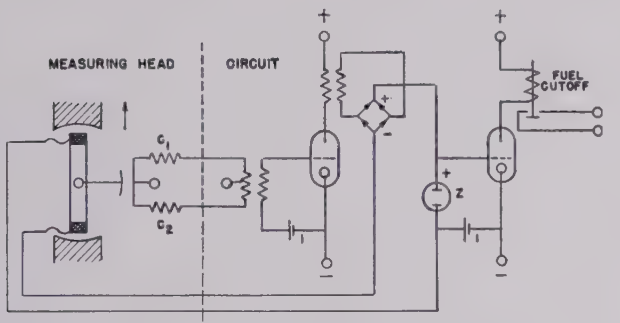



**Figure 3. Diagram of the Buchhold integrating accelerometer**

acceleration and hence its velocity. Further, a double integration of acceleration measures distance. Signal for combustion cutoff of the rocket fuel is given by a counter which actuates a relay when the gyroscope has precessed through a predetermined number of revolutions. Manual setting of the preset vernier adjusts a cam which determines the fuel cutoff. The exact setting required is determined from firing tables, which allow for empirical data obtained by bench tests and for a correction for the calculated vertical component of the acceleration of gravity, made from the observed precession rate of the gyro under the influence of gravity for various tilt angles of the missile while in flight.

This device is reportedly capable of providing the *A-4* with a range accuracy within approximately five miles up to 190 miles range.

Several mechanical accelerometers capable of performing a double integration of acceleration were constructed. These used the precessing gyroscope principle in combination with a ball-and-disk arrangement common to computers, but none of these were flight-tested because of the development of devices of greater accuracy.

A second device developed under the direction of Professors Theodore Buchhold and Carl Wagner was an electrolytic integrating accelerometer which eliminated some of the errors inherent in the mechanical accelerometer. It is shown schematically in Figure 3. A photograph of this device is shown in the July 1946 issue of *Electrical Engineering*.[1]

A pivoted arm is fitted with a copper slug which, when moved within the poles of two electromagnets, $C_1$ and $C_2$, unbalances a bridge circuit. The signal thus obtained is amplified, rectified, and fed into an erecting coil in a permanent-magnet field. In series with this coil is an electrolytic cell, $Z$, arranged so that the current flowing through the coil and cell unit causes a chemical change within each cell at a rate determined by the acceleration.

The Wagner electroplating cell, $Z$, consists of two silver electrodes, *1* and *2*, covered with solid silver chloride and acetic acid to warrant a definite hydrogen-ion concentration. After electrolytic reduction of the silver chloride on electrode *1*, a definite quantity of silver chloride is deposited on this electrode for calibration purposes by a current whose magnitude is determined by the deflection, caused by gravity, of the copper slug for a predetermined period. During the power-on portion of flight, the silver chloride on electrode *1* is reduced gradually by the reversed current determined by the acceleration of the missile plus gravity. When all of the silver chloride on electrode *1* has been reduced, hydrogen is evolved. The process requires a higher electrical potential, and therefore, the potential of the cell jumps by approximately one volt. The signal thus obtained is amplified and then is used to reduce the fuel supply into the combustion chamber, reducing the rocket thrust from 25.6 tons to 8 tons. A second integration performed in a similar manner in a second cell was used to obtain the signal for the final cutoff.

Military operations required using Wagner cell units during various seasons of the year. This led to temperature regulation of the cell because of variation in the solubility of silver chloride with temperature. This regulation was provided by a thermostat which controlled a heating element wound around the individual cells.

Laboratory tests indicate that the Wagner cell is accurate within an average deviation of 0.03 per cent. The Buchhold measuring head is accurate to 0.08 per cent. Variations in instrument constants during flight are reduced by dispersion of the resonant vibration peaks for the instrument and for the control compartment of the missile.

## THE *A-4* TRAJECTORY

Errors of considerable magnitude occur in any scheme which measures only the velocity vector as a means for range control. These errors are inherent in both of the accelerometers already described.

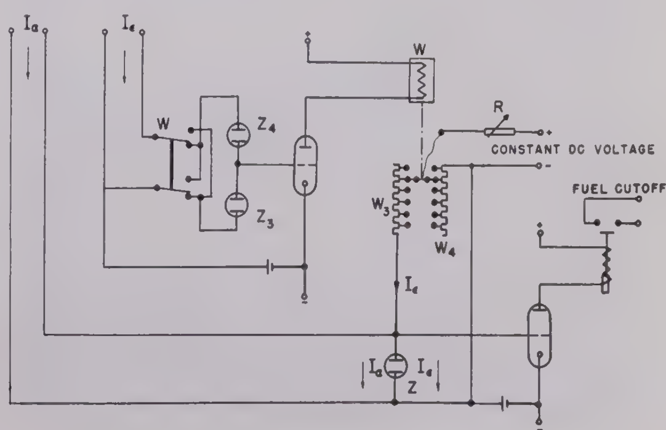



**Figure 4. Buchhold double-integrating accelerometer**

One error is related to the distance traveled by the missile during propelled flight. If the thrust unit accelerates the rocket at a rate greater than anticipated, combustion cutoff will occur too soon; the missile will fall short of its target and vice versa. A stopgap remedy for this is to use a time-measuring device, so that a definite time must elapse before cutoff. This system was used for each of the foregoing integrators. By calculation it may be shown, that, within limits, a deviation of the average thrust of the *A-4* rocket motor by one per cent above or below the normal may result in a one-fourth-mile deviation from the desired range. The vertical component of the acceleration of gravity is also a source of error. For any exact, predetermined trajectory, it is possible to compensate for this, but in each case deviation from the anticipated trajectory will cause burning cutoff too early or too late.

Errors also may result from centrifugal forces, which are encountered on the gyroscope or on the measuring head as the missile is programmed, if these devices are mounted in a fixed position relative to the missile.

These errors and considerations involving lateral control of the missile led to the development of a platform horizontally stabilized by three gyroscopes. Measuring heads for the electrolytic accelerometers are mounted on this platform. The *A-4* stable platform provides a reference basis accurate within a drift rate of 0.05 degree per minute. Such accuracy is desired because, for missiles with short time of powered flight, the errors caused by platform drift increase approximately as the cube of the time during which measurements are made.

Returning to the range error produced by variations in the thrust program: a measure of the distance covered by the rocket may be obtained by a double integration of the acceleration. Assuming that velocity and distance covered by the rocket are known, if the measuring heads of accelerometers used for performing the first and second integrations are specially mounted on a stable platform, and if Wagner electrolytic cells are used for integrating, the dispersion in range of the *A-4* over a 200-mile course may be expected to be of the order of one mile.

From a study of trajectories, it was found that the foregoing result may be anticipated by mounting the two integrating measuring heads on the stable platform at different angles from the vertical with respect to the axis of the missile for the first and second integrations respectively. A close approximation of the final velocity desired for cutoff may be expressed as the velocity obtained by the first integration plus some constant times the distance covered during the burning period. The *A-4* range constants for various angles of measuring-head settings and values of resistance, $R$, are available from firing tables.

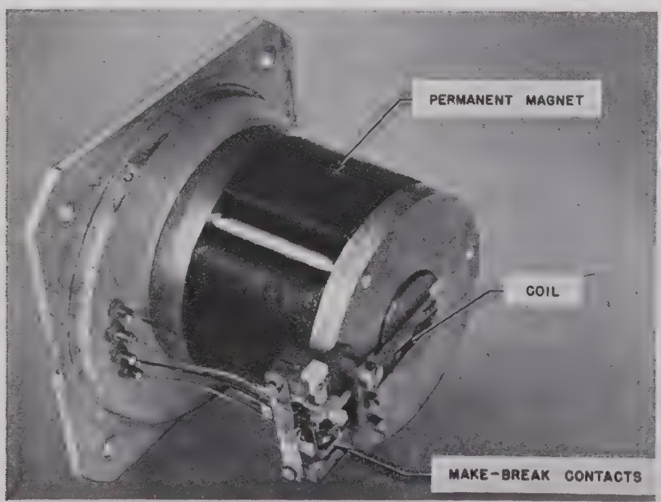



**Figure 5. Schlitt integrating accelerometer**

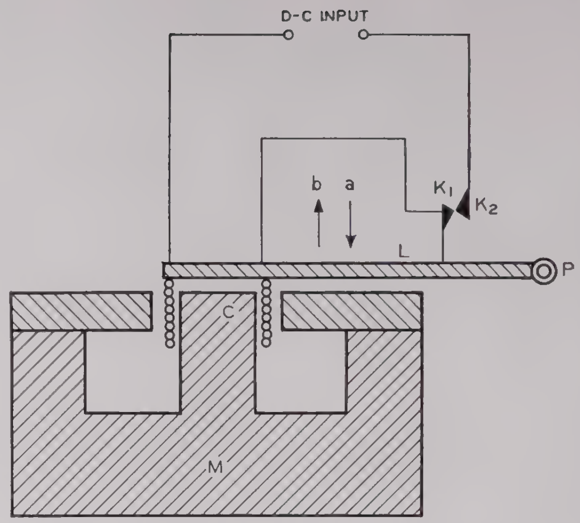



**Figure 6. Schlitt accelerometer measuring head**

The Buchhold system for compensating cutoff velocity corresponding to the distance traveled by the rocket is shown in Figure 4. The principle involves a single integration of acceleration to measure velocity and a compensating double integration of acceleration to measure distance. From one of two measuring heads mounted on a stabilized platform, the current $I_\alpha$ proportional to the acceleration of the rocket, is fed into cell unit $Z$ where it is integrated. At the same time a current $I_\epsilon$ from the second measuring head is fed into cell units $Z_3$ and $Z_4$ which previously have been plated with different polarities. When a signal is received from either of the cell units $Z_3$ or $Z_4$, relay $W$ is actuated and causes step relay $W_3$, $W_4$, to assume a new position. This reverses the polarity of cell units $Z_2$ and $Z_4$ and also changes the value of resistance acting in series with resistance $R$.

Depending upon the current flowing through external resistance $R$, the cutoff signal which finally must be received from cell $Z$ is influenced to provide a corrective signal effected by the constants fed into the cell through 12 steps provided by the step relay. The device described, therefore, compensates cutoff velocity depending upon distance covered by the rocket during propulsion.

Following preliminary cutoff from 26 tons to 8 tons of thrust, acceleration continues to be integrated at a much reduced rate, and final cutoff can be performed within desired tolerances. When the acceleration is reduced, dispersions in the time constants of various relays have less influence on the desired range. Since the accuracy of the Buchhold accelerometer is within the limits of dispersion provided by the relays and valves, a more accurate com-

bustion cutoff than provided by the *A-4* would involve redesign of many valves and relays.

## LATERAL GUIDANCE

Lateral control of the *A-4* may be accomplished by a guide-beam system or by a Schlitt lateral accelerometer.

The German radio guide-beam system, which operates at a frequency of 50 megacycles, consists of a transmitter on the ground lobeswitching two widely separated dipoles 120 degrees out of phase. The receiver is located in the control compartment of the missile and measures lateral deviations from the anticipated trajectory by means of the comparative signals received from the beam. Because of the low frequency used, the system is sensitive to terrain and the presence of aircraft in the vicinity of the line of flight. Under proper conditions, it is capable of providing a lateral accuracy of three yards at a slant range of 20 miles.

## SCHLITT LATERAL ACCELEROMETER

A simpler and jamproof system, used mainly for *A-4* lateral guidance, consists of the Schlitt Integrating Accelerometer, shown in Figures 5 and 6, which may be mounted on a stabilized platform. This accelerometer consists of a moving coil, *C*, concentric with the center pole of a loud-speaker magnet and free to move about external pivot *P*. Attached to lever *L* is a contact $K_1$, which touches fixed contact $K_2$ when the lever *L* is moved in direction *a*, thereby energizing coil *C*. When the contacts are closed, the resulting force causes the coil to move in direction *b*, thus again opening the contacts. It can be shown that an acceleration of the unit controls the average current through the coil in proportion to the acceleration, and this measurement is linear through zero acceleration.

Such a system provides information in only one direction. By use of a bridge circuit, however, equally accurate data are obtained for either direction. This current may be integrated once, twice, or three times in a capacitor network in order to measure velocity, distance, or the integral of distance as a function of time, respectively.

Figure 7 indicates the system for measuring lateral deviations in either direction. The make-and-break contacts from the accelerometer form one leg of the bridge circuit.

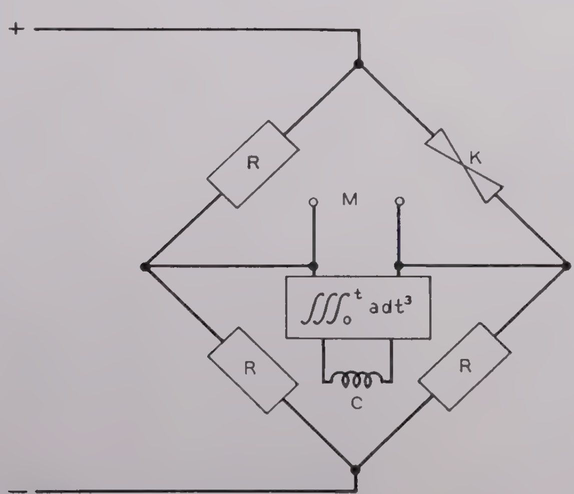



**Figure 7. Bridge circuit for Schlitt accelerometer**

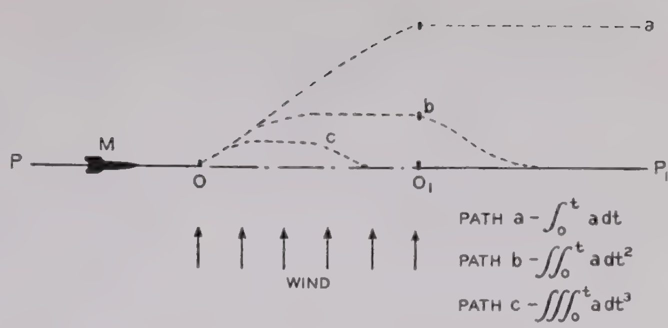



**Figure 8. Lateral deviation from course due to side winds**

Moving coil *C*, therefore, receives a current proportional to the average current flowing through the contacts. Output from the coil is integrated three times and fed into mixing computer, *M*. Devices which measure lateral accelerations must provide continuous information to the rudders so that the direction of the missile at fuel cutoff will be correct. To obtain the required accuracy, it is necessary to mount the lateral accelerometer on a stabilized platform. Such a mounting assures measurement in a lateral direction normal to the prescribed trajectory. As with all accelerometers, the error effected by the stabilized platform for short times of flight may be shown to be approximately proportional to the cube of the flight time, since lateral deviations (distance) are a function of time squared and the drift of the stabilized platform is linear with time. The German stabilized platform drifts 0.05 degree per minute.

## THE *A-4* LATERAL TRAJECTORY

The close tolerances required in the lateral control of the *A-4* make it advantageous to perform a triple integration of the lateral acceleration. Consider a missile, *M*, which is to be guided along path $P$–$P_1$ under the influence of the side winds in the region $O$–$O_1$ (Figure 8). The missile has followed a prescribed course to point *O*, where winds produce a lateral acceleration. For a single integration of this acceleration the rudders will assume a position sufficient to eliminate the lateral velocity, but the missile cannot return to the prescribed course and continues on path *a*.

Somewhat better results are attained when a double integration of the lateral acceleration is performed. Under the influence of the side winds, starting at point *O*, the missile moves laterally from the prescribed course, and a signal is transmitted to the missile rudders proportional to the lateral distance through which the missile has moved. Only upon termination of the side winds will the missile return to the prescribed course. Obviously, where propulsion cutoff must be accomplished under the influence of side winds, impact errors will result.

If a triple integration of the lateral acceleration is performed, the signal provided to the rudders will be proportional to the lateral distance covered multiplied by the integral of time. The longer the missile is maintained off the prescribed course, the larger will become the deflection of the rudders. The missile therefore, will return to the desired path in spite of the influence of side winds.

## REFERENCE


1. V-2 Range Control Technique, **Thomas M. Moore.** *Electrical Engineering,* volume 65, number 7, July 1946, pages 303–05.

# INSTITUTE ACTIVITIES

## Early Hotel Reservations Urged for Winter Meeting

As announced in the list of future AIEE meetings in *Electrical Engineering*, the 1950 AIEE Winter General Meeting will be held in New York, N. Y., during the week of January 30 through February 3, 1950. Meeting headquarters will be at the Hotel Statler with all activities centered at that hotel, except for the smoker. Most of the technical committees are planning to sponsor sessions and it is expected that the technical program will consist of at least 60 technical sessions and conferences. An interesting series of inspection trips is being planned to supplement the formal technical program. Plans are also under way for both a smoker and a dinner-dance. An extensive program of entertainment for the ladies attending the meeting is being arranged. For the accommodation particularly of the members coming from out of town, blocks of theater tickets for popular New York shows will be made available for sale in advance of the meeting date.

### HOTEL RESERVATIONS

Blocks of rooms have been set aside at the Hotel Statler (meeting headquarters) and nearby hotels for members attending. Requests for reservations should be sent early directly to the hotel of choice, and to only one hotel. A copy of the request should be sent to C. N. Metcalf, Vice-Chairman, Hotel Reservations, in care of Consolidated Edison Company of New York, Inc., Room 1350S, 4 Irving Place, New York 3, N. Y., and a second and third choice should be indicated thereon. If accommodations are not available, the Hotel Reservations Committee will arrange for transfer of the request for reservations to one of the other convenient hotels.

Hotel rooms have been reserved at the following:

| | |
|---|---|
| **Hotel Statler (formerly Pennsylvania)** meeting headquarters, 7th Avenue, 32d to 33d Streets | |
| Single room with bath | \$ 4.50 to \$ 8.50 |
| Double room, double bed | 7.00 to 10.50 |
| Double room, twin beds | 8.00 to 14.00 |
| **Hotel McAlpin,** Broadway and 34th Street | |
| Single room and bath | 4.00 to 7.00 |
| Double room, double bed | 6.50 to 10.00 |
| Double room, twin beds | 7.50 to 11.00 |
| Suites | 13.00 to 16.00 |
| **Hotel Governor Clinton,** 7th Avenue at 31st Street | |
| Single room with bath | 4.00 to 6.00 |
| Double room, double bed | 6.50 to 8.00 |
| Double room, twin beds | 8.00 to 9.50 |
| **Hotel New Yorker,** 34th Street at 8th Avenue | |
| Single room, tub and shower | 4.50 to 8.00 |
| Double room, double bed | 7.00 to 12.50 |
| Double room, twin beds | 8.00 to 12.50 |
| **Hotel Martinique,** Broadway and 32d Street | |
| Single room with bath | 4.00 to 5.50 |
| Double room with bath | 6.00 to 8.00 |
| Double room, twin beds | 6.50 to 8.00 |

## Additional Section Officers Announced

The following new officers of Sections have been recorded at Institute headquarters since the publication of the list of Section officers in the September issue of *Electrical Engineering* (*p 805*):

**Boston Section**
*Secretary:* Leslie J. Weed, Boston Edison Company, 182 Tremont Street, Boston, Mass.

**Florida Section**
*Chairman:* Jess D. Thomas, P. O. Box 4817, Jacksonville, Fla.
*Secretary:* J. D. Griffin, P. O. Box 26, Station G, Jacksonville, Fla.

## Future AIEE Meetings

**AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine**
Hotel Commodore, New York, N. Y.
October 31–November 2, 1949

**Winter General Meeting**
Hotel Statler, New York, N. Y.
January 30–February 3, 1950
(*Final date for submitting papers—closed*)

**AIEE Conference on Electric Power Supply for Industrial Plants**
Hotel William Penn, Pittsburgh, Pa.
April 1950

**AIEE Conference on Meeting Load Demands With Limited Reserve**
Hotel William Penn, Pittsburgh, Pa.
April 1950

**AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industry**
Akron, Ohio
April 1950

**AIEE Conference on Electric Welding**
Detroit, Mich.
April 5–7, 1950

**North Eastern District Meeting**
Providence, R. I.
April 26–28, 1950
(*Final date for submitting papers—January 26*)

**Great Lakes District Meeting**
Jackson, Mich.
May 11–12, 1950
(*Final date for submitting papers—February 10*)

**Summer and Pacific General Meeting**
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(*Final date for submitting papers—March 14*)

**Fall General Meeting**
Oklahoma City, Okla.
October 23–27, 1950
(*Final date for submitting paper—July 25*)

**1951 Winter General Meeting**
New York, N. Y.
January 29–February 2, 1951
(*Final date for submitting papers—October 31*)

## Committee Appointed for 1950 Fall General Meeting

According to a recent announcement, AIEE President Fairman has appointed members of the general committee to make plans for the AIEE Fall General Meeting which is to be held in Oklahoma City, Okla., October 23–27, 1950. These will include the following:

W. B. Stephenson, *Chairman;* R. F. Danner, *Vice-Chairman;* F. J. Meyer, *Vice-Chairman;* R. Randall, *Vice-Chairman*

Also the following committee chairmen:

E. W. Allen, *Publicity;* Bryce Brady, *Program;* Otis Howard, *Inspection Trips;* George Larason, *Entertainment;* J. S. Joseph, *Sports;* J. S. Wantland, *Finance,* R. L. Jones, *Hotel;* G. E. Taylor, *Registration*

# COMMITTEE NOTES •

*Editor's Note: This department has been created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.*

### General Applications Group

**Subcommittee on Nomenclature for Electronic Lamps of Committee on Production and Application of Light** (*R. C. Putnam, Present Chairman*). This subcommittee, while composed of E. H. Salter, *Chairman,* E. W. Beggs, L. R. Keiffer, R. C. Putnam, and T. C. Sargent, prepared definitions for 47 terms used in connection with electric discharge lamps and a classification of these lamps according to: the source of their radiant energy; the type of discharge; and the pressure of the medium. A report covering this work has been submitted to the parent committee and in turn transmitted to the AIEE Committee on Electronics and the Illuminating Engineering Society Committee on Nomenclature for comment and criticism.

### Industry Group

**Subcommittee on Revision of Electric Power Distribution for Industrial Plants of Committee on Industrial Power Systems** (*John Grotzinger, Chairman*). This subcommittee has been working on a revision of the popular Red Book to bring it up to date. Individual chapters have been undergoing revision by small groups. The new edition will be of improved appearance, expanded to perhaps twice the present size with additional material on voltage recommendations,

relay settings, d-c fault data, and will be more generally useful. It is hoped to have the work completed during the year and the booklet available shortly thereafter.

**Subcommittee on Interior Wiring Design for Commercial Buildings of Committee on Industrial Power Systems** (*B. F. Thomas, Chairman; L. W. McCullough, Secretary, 1948–49*). This subcommittee has completed its work on a report, which was presented at the Fall General Meeting in Cincinnati and has been published as a special publication (80 cents to nonmembers; 40 cents to members). This published report includes considerable material on distribution systems in buildings, and reasons for methods recommended; also cost data for estimating purposes, emergency lighting circuits, and communications and alarm systems.

### Power Group

**Insulation Levels for Relay and Control Circuits Project Committee for the AIEE Relay Committee** (*E. L. Michelson, Chairman*). This committee was organized to study the insulation levels required in relay circuits to protect against high voltages induced in these circuits by sudden interruption of current to the various solenoids used in the control system. A value of 1,500 volts alternating current has been adopted as being an adequate test voltage for both the d-c and a-c circuits associated with relays. It has been agreed that to protect against the possibility of higher voltages, various protective devices may be used, such as shunting resistors and capacitors.

The studies of this committee are summarized in a paper presented at the Fall General Meeting. One of the conclusions reached by the committee was that there is need for a voltage limitation on the control circuits of circuit breakers. It has been requested that a future revision of the Circuit Breaker Standard should include such a limitation.

**System Operations Subcommittee of the System Engineering Committee** (*O. W. Manz, Jr., Chairman*). This subcommittee is planning a session for the New York Winter General Meeting on the subject "Operation of Power Systems at Leading Power Factor." This very live and timely topic has been brought to the fore in system operators minds by the very high power factor that is now being experienced in light load periods. This is largely the results of improvement in the power factor of the larger motor loads and the almost universal adoption of static capacitors on the distribution systems.

At this session it is expected that some of the manufacturers as well as the system operators and system designers will discuss the desirability and the precautions which must be taken when operating power systems in the leading power factor range.

In order to have a full and comprehensive discussion from as broad a segment of members as possible, it has been decided that all papers will be limited to conference type. It is hoped from the discussion and experience related that there will be increased confidence instilled in the operators' minds in the performance of generators in the leading power factor range.

**Generator Protection Project Committee of the Relay Committee** (*H. R. Paxson, Chairman*). This project committee was formed to investigate the various practices in use in the field of generator protection. Recent developments have led to the need for information on various subjects relating to methods of relay protection. One of these is the increased use of loss-of-excitation protection, which has been given considerable attention in recent years. Two papers on this problem were presented at the Summer General Meeting. An effort has been made to obtain data on the effect of partial winding faults, and papers on this subject are being encouraged.

The project committee has recently prepared a questionnaire covering all phases of this subject. In the near future, this questionnaire will be sent to a number of protection engineers throughout the United States, and the answers received will be made the basis of a future report by this project committee.

### Science and Electronics Group

**Committee on Metallic Rectifiers** (*L. O. Grondahl, Chairman; I. R. Smith, Vice-Chairman; E. A. Harty, Secretary*). A fifth edition of the "Metallic Rectifier Definitions and Test Standards" is ready to go to press. This edition will contain the latest revised definitions as well as test information for use in testing metallic rectifier units. A new section on "Stack Testing" is in preparation. A subcommittee to study "Miniature and Instrument-Type Metallic Rectifiers" is in the process of being organized.

# Section and Branch Activities—Annual Report for 1948-1949

The following constitutes the annual report on Institute Section and Branch activities for the fiscal year which ended April 30, 1949. Similar information for three preceding fiscal years appeared in *Electrical Engineering*, November 1948, pages 1117–20; August 1947, pages 837–40; July 1946, pages 352–4.

Members of the 1948–1949 committees supervising the divisions of Institute activities covered by this report are

*Sections*—J. C. Strasbourger, *Chairman;* C. S. Purnell, *Vice-Chairman (East)*; D. I. Anzini, *Vice-Chairman (West)*; T. J. Martin, *Secretary;* W. J. Barrett, F. S. Black, F. D. Bolton, G. W. Bower, S. C. Commander, H. A. Dambly, W. A. Dynes, O. R. Enriquez, C. W. Fick, H. W. Haberl, R. C. Horn, W. H. D. Horsfall, R. E. Kistler, C. P. Knost, C. W. Lethert, W. I. Middleton, L. R. Patterson, F. H. Pumphrey, R. V. Shepherd, E. W. Stone, and, ex-officio, Chairmen of Sections

*Student Branches*—H. N. Muller, Jr., *Chairman;* L. T. Rader, *Vice-Chairman;* B. S. Willis, *Secretary;* Sterling Beckwith, J. F. Calvert, P. L. Hoover, J. H. Kuhlmann, J. D. McCrumm, F. O. McMillan, W. H. Pickering, R. G. Porter, R. W. Warner, and, ex-officio, Counselors of Student Branches

**Table I. Section Membership and Meetings During Year Ending April 30, 1949**

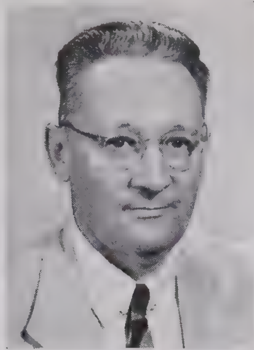
| Section | AIEE Members August 1948 | AIEE Members August 1949 | Number of Meetings | Total No. Meetings |
|---|---|---|---|---|
| Akron | 109 | 118 | 9 | 9 |
| Alabama | 158 | 199 | 9 | 9 |
| Arizona | 112 | 131 | 9 | |
| Groups: Distribution | | | 2 | |
| Electronics | | | 2 | |
| Power | | | 1 | 14 |
| Arkansas | 77 | 79 | 12 | |
| Group: Technical | | | 2 | |
| Subsection: Northwest Arkansas | | | 1 | 15 |
| Arrowhead | 39 | 43 | 9 | 9 |
| Beaumont | 78 | 81 | 12 | 12 |
| Boston | 803 | 833 | 8 | |
| Groups: Basic Science | | | 2 | |
| Distribution | | | 3 | |
| Electronics | | | 2 | |
| Industrial Power Applications | | | 1 | |
| Instruments and Measurements | | | 3 | |
| Insulation | | | 2 | |
| Land Transportation | | | 2 | |
| Power Generation | | | 2 | |
| Transmission | | | 3 | |
| Wire Communications | | | 1 | |
| Subsection: New Hampshire | | | 1 | 30 |
| Canton | 69 | 79 | 11 | |
| Group: Electronics | | | 2 | 13 |
| Central Indiana | 222 | 232 | 11 | 11 |
| Chicago | 1,487 | 1,587 | 6 | |
| Groups: Basic Science | | | 3 | |
| Communications | | | 3 | |
| Electronics | | | 5 | |
| Industrial | | | 5 | |
| Power | | | 4 | 26 |
| Cincinnati | 205 | 236 | 11 | |
| Group: Technical | | | 4 | 15 |
| Cleveland | 629 | 708 | 9 | |
| Groups: Basic Science | | | 3 | |
| Electrical Measurements | | | 3 | |
| Motors and Control | | | 7 | |
| Power Generation and Distribution | | | 1 | 23 |
| Columbus | 131 | 137 | 10 | |
| Group: Study | | | 10 | |
| Subsection: Zanesville | | | 12 | 32 |
| Connecticut | 492 | 490 | 8 | 8 |

(*Continued on page 1005*)

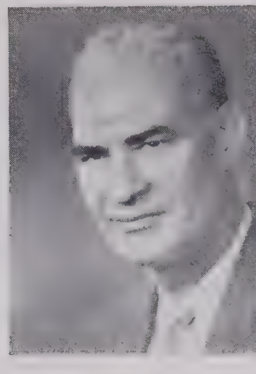
# Introducing AIEE Section

*Some of the men who will preside over*

H. P. Davis
(*Akron Section*)

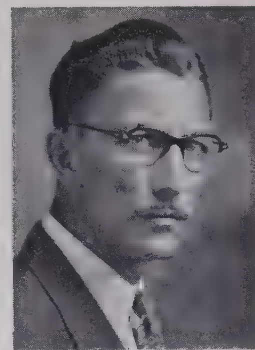


*Birmingham News* photo
J. W. Davis
(*Alabama Section*)



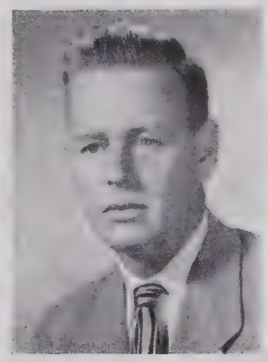
W. B. Bustard
(*Arizona Section*)

W. A. Lewis, Jr.
(*Arkansas Section*)

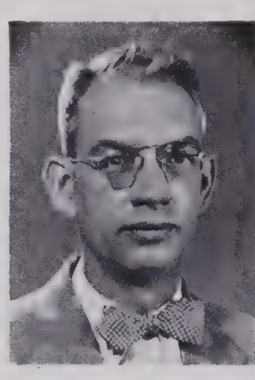


P. A. Beckjord
(*Arrowhead Section*)

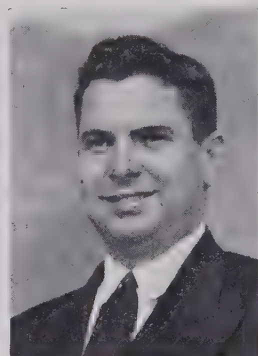
J. J. Loustaunau
(*Boston Section*)



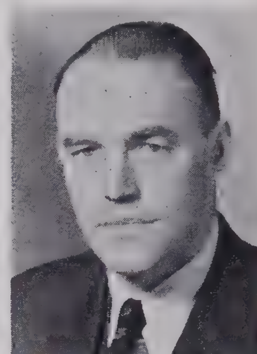
R. W. Parker
(*Beaumont Section*)



C. L. Lucal
(*Canton Section*)



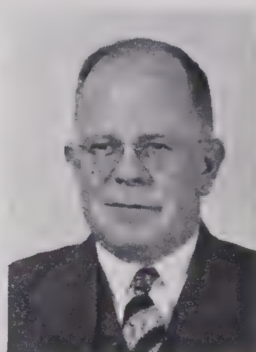
G. M. Grabbe
(*Central Indiana Section*)



H. E. Nason
(*Chicago Section*)

F. E. Wiatt
(*Cincinnati Section*)

R. L. Oetting
(*Cleveland Section*)

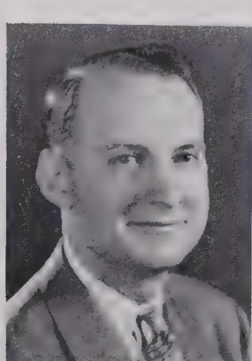


J. B. Powell
(*Connecticut Section*)

N. L. Greene
(*Columbus Section*)

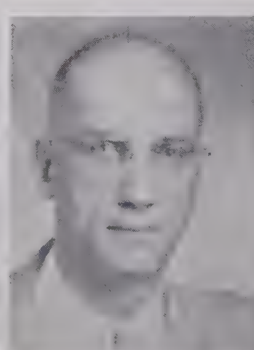
Eugene Herzog
(*Dayton Section*)

T. D. Talmage
(*East Tennessee Section*)



M. J. Kolhoff
(*Erie Section*)

J. D. Thomas
(*Florida Section*)

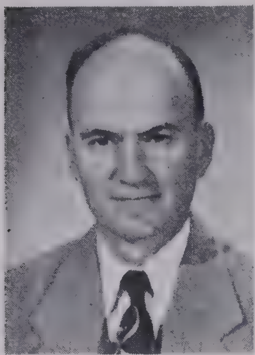


J. F. Eitman
(*Fort Wayne Section*)

E. S. Lammers
(*Georgia Section*)

# Chairmen for 1949-50

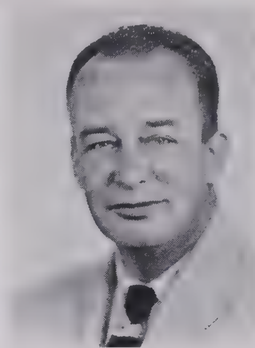
*AIEE Sections during the 1949–50 term*



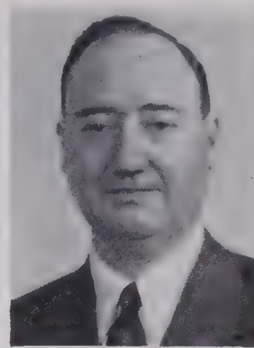
**W. O. Ray**
*(Houston Section)*

**E. W. Stone**
*(Illinois Valley Section)*

**T. W. Schroeder**
*(Iowa Section)*



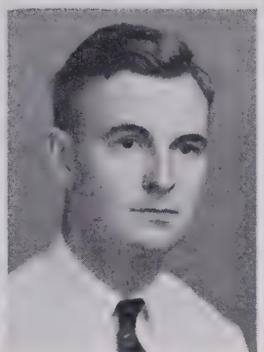
**H. L. Livingood**
*(Ithaca Section)*



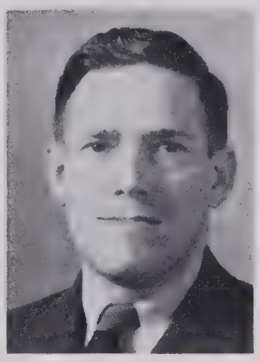
**R. M. Kerchner**
*(Kansas City Section)*

**C. H. Sprague**
*(Lehigh Valley Section)*

**E. L. Bettannier**
*(Los Angeles Section)*



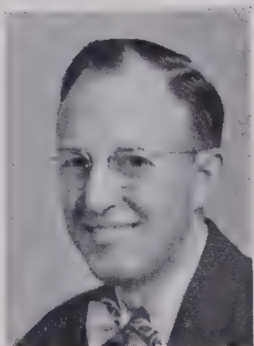
**R. D. Spalding**
*(Louisville Section)*



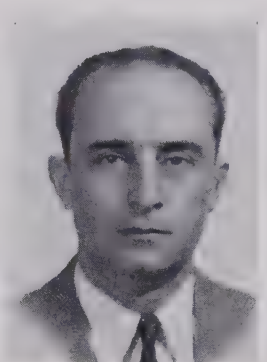
**R. S. Schlotterbeck**
*(Lynn Section)*

**E. C. Ryan**
*(Mansfield Section)*

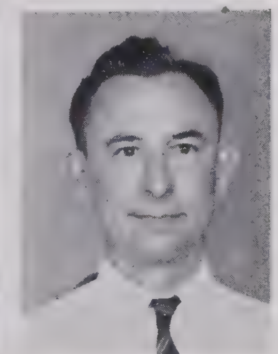
**F. H. Rogers**
*(Maryland Section)*



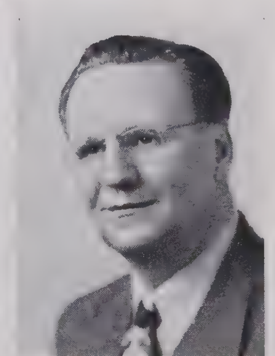
**W. B. Thompson**
*(Memphis Section)*



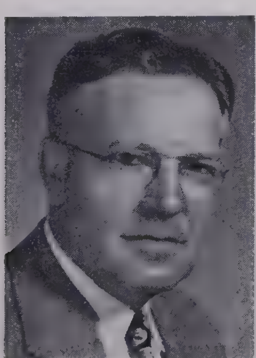
**E. D. Luque**
*(Mexico Section)*



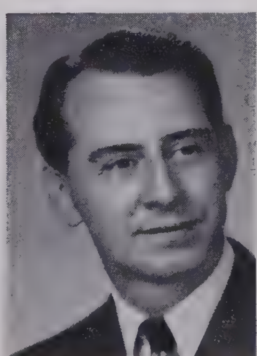
**C. H. Summers**
*(Miami Section)*



**L. A. Rietow**
*(Minnesota Section)*



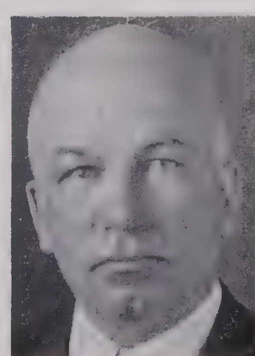
**E. F. Dissmeyer**
*(Michigan Section)*



**F. J. Van Zeeland**
*(Milwaukee Section)*

**J. R. Walker**
*(Montana Section)*

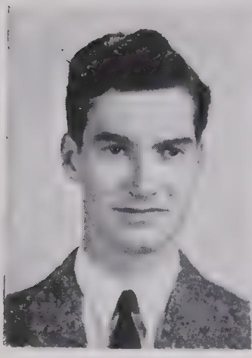
**O. H. Gutsch**
*(New Mexico–W. Texas Sec.)*



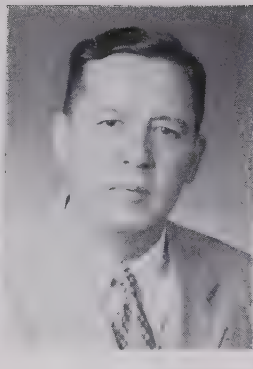
**N. L. Morgan**
*(Montreal Section)*

# Introducing AIEE Section

*Continued from*



**F. C. Howard**
*(Nebraska Section)*



**E. I. Blanchard**
*(New Orleans Section)*

**D. W. Taylor**
*(New York Section)*

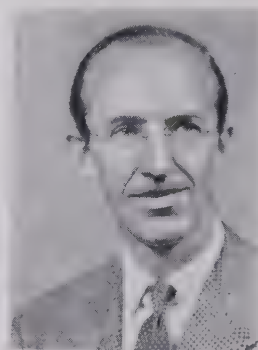
**F. C. Rushing**
*(Niagara Frontier Section)*

**W. G. A. Barr**
*(Niagara International Sec.)*

**G. G. Mattison**
*(North Carolina Section)*

**P. G. Wallace**
*(North Texas Section)*

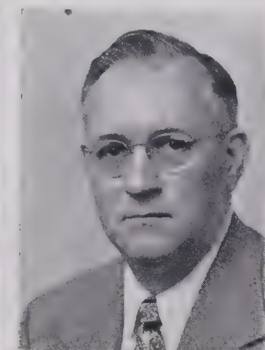
**E. W. Allen**
*(Oklahoma City Section)*



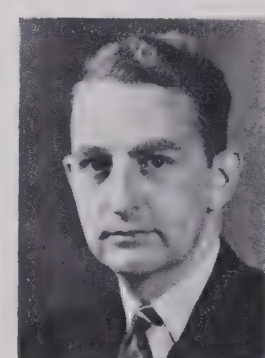
**F. A. Fleming**
*(Ottawa Section)*

**G. W. Dupree**
*(Panhandle Plains Section)*

**W. F. Henn**
*(Philadelphia Section)*



**F. H. Schlough**
*(Pittsburgh Section)*

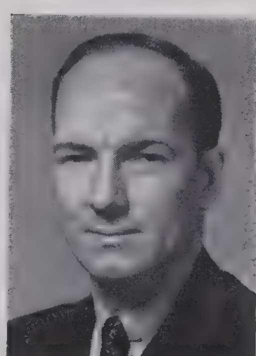


**T. E. Rodhouse**
*(Pittsfield Section)*

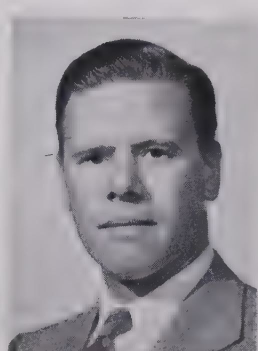
**R. B. Temple**
*(Portland Section)*

**O. E. Sawyer**
*(Providence Section)*

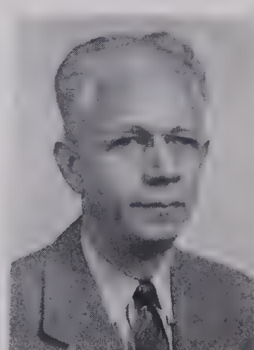
**W. J. Dowis**
*(Richland Section)*



**J. H. Rogers**
*(Rochester Section)*



**S. A. Coxhead**
*(Rock River Valley Section)*



**R. C. Horn**
*(St. Louis Section)*

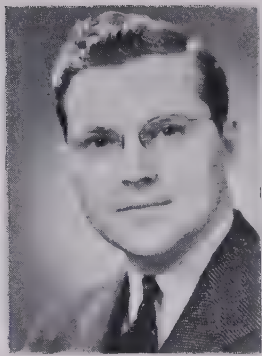
**J. F. Sinnott**
*(San Diego Section)*

# Chairmen for 1949-50

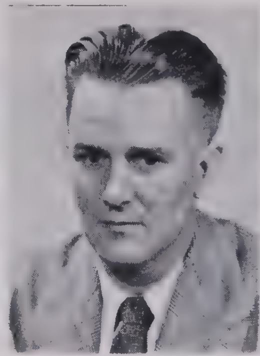
*preceding page*

**T. C. McFarland**
*(San Francisco Section)*

**Ray Rader**
*(Seattle Section)*

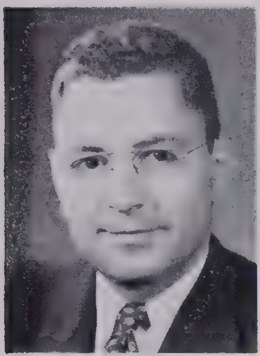


**J. C. Page**
*(Schenectady Section)*



**G. R. Monroe**
*(Sharon Section)*

**L. T. Williams**
*(Shreveport Section)*

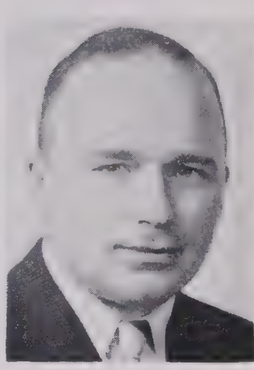


**R. A. Cliff**
*(South Bend Section)*

**E. P. Miller**
*(South Carolina Section)*

**L. L. Antes**
*(South Texas Section)*

**T. W. MacLean**
*(Spokane Section)*



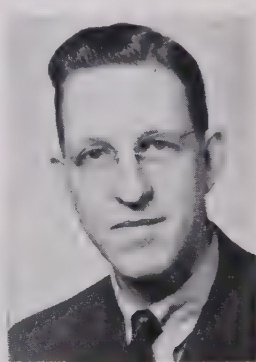
**J. M. Somerville**
*(Toronto Section)*

**Dick Ray**
*(Tulsa Section)*

**F. A. Furfari**
*(Toledo Section)*

**H. N. Hayward**
*(Urbana Section)*

**F. O. Wald**
*(Utah Section)*

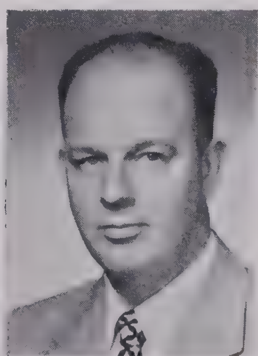


**W. J. Lind**
*(Vancouver Section)*

**Llewellyn Saunders**
*(Virginia Section)*

**Dixon Lewis**
*(Washington Section)*

**E. B. Ellerbe**
*(West Virginia Section)*



**I. H. McMann**
*(Western Virginia Section)*

**D. R. Percival**
*(Worcester Section)*

(Continued from page 1001)

**Table I (continued). Section Membership and Meetings During Year Ending April 30, 1949**

| Section | AIEE Members August 1948 | AIEE Members August 1949 | Number of Meetings | Total No. Meetings |
|---|---|---|---|---|
| Dayton | 300 | 341 | 13 | |
| Groups: Aeronautics | | | 4 | |
| Electronics | | | 2 | |
| Motors and Controls | | | 3 | |
| Subsection: Lima | | | 5 | 27 |
| Denver | 338 | 367 | 13 | |
| Groups: Communications | | | 6 | |
| Electric Equipment | | | 7 | |
| Power Systems | | | 6 | |
| Subsection: Casper, Wyo. | | | 4 | 36 |
| East Tennessee | 342 | 415 | 21 | |
| Subsection: Oak Ridge | | | 8 | 29 |
| Erie | 120 | 130 | 9 | 9 |
| Florida | 225 | 137 | 4 | |
| Subsections: Jacksonville | | | 2 | |
| Miami | | | 5 | |
| West Coast | | | 1 | 12 |
| Fort Wayne | 114 | 125 | 9 | 9 |
| Georgia | 207 | 220 | 10 | 10 |
| Houston | 246 | 271 | 9 | |
| Groups: Communications | | | 3 | |
| Geophysical | | | 2 | |
| Industrial Applications | | | 7 | |
| Subsection: Freeport | | | 11 | 32 |
| Illinois Valley | 117 | 151 | 18 | |
| Group: Technical | | | 14 | |
| Subsection: Sangamon | | | 3 | 35 |
| Iowa | 159 | 187 | 15 | |
| Subsection: Quad Cities | | | 5 | 20 |
| Ithaca | 158 | 180 | 9 | |
| Groups: Basic Sciences | | | 6 | |
| Technical | | | 7 | |
| Subsection: Binghamton Area | | | 5 | |
| Binghamton Area Technical Group | | | 3 | 30 |
| Kansas City | 228 | 272 | 15 | |
| Groups: Human Aspects of Engineering | | | 1 | |
| Industrial Practices | | | 8 | |
| Meter and Relay | | | 3 | |
| Nuclear Physics | | | 6 | 33 |
| Lehigh Valley | 281 | 324 | 9 | 9 |
| Los Angeles | 1,179 | 1,289 | 10 | |
| Groups: Aircraft | | | 6 | |
| Electronics | | | 4 | |
| Power | | | 8 | |
| Subsection: Boulder City | | | 8 | 36 |
| Louisville | 110 | 115 | 9 | 9 |
| Lynn | 228 | 266 | 22 | 22 |
| Madison | 82 | 75 | 9 | 9 |
| Mansfield | 68 | 74 | 10 | 10 |
| Maryland | 536 | 626 | 9 | |
| Groups: Communications | | | 3 | |
| Industrial Electronics | | | 2 | |
| Power | | | 4 | |
| Subsection: Lancaster-York | | | 7 | 25 |
| Memphis | 106 | 124 | 11 | |
| Subsection: Nashville | | | 2 | 13 |
| Mexico | 202 | 216 | 8 | 8 |
| Miami | | 97 | 3 | 3 |
| Michigan | 695 | 805 | 13 | |
| Groups: Round Table | | | 5 | |
| Electronics | | | 1 | |
| Instruments and Measurements | | | 2 | |
| Welding | | | 3 | |
| Subsection: Saginaw Valley | | | 9 | 33 |
| Milwaukee | 621 | 688 | 10 | |
| Groups: Audio | | | 5 | |
| Basic Science | | | 3 | |
| Electric Machinery | | | 4 | |
| Electronics | | | 4 | |
| Power Application and Control | | | 2 | |
| Transmission and Distribution | | | 3 | |
| Subsection: Fox River Valley | | | 8 | 39 |
| Minnesota | 240 | 279 | 16 | |
| Groups: Communication | | | 1 | |
| Electronics | | | 1 | |
| Power | | | 1 | |
| Subsection: Red River Valley | | | 12 | 31 |
| Montana | 84 | 90 | 4 | |
| Subsections: Billings | | | 4 | |
| Great Falls | | | 9 | |
| Great Falls Power System Group | | | 3 | 20 |
| Montreal | 308 | 296 | 15 | |
| Subsections: Ottawa | | | 12 | |
| St. Maurice Valley | | | 7 | 34 |
| Muscle Shoals | 23 | | 1 | 1 |
| Nebraska | 85 | 108 | 8 | 8 |
| New Mexico-West Texas | 108 | 148 | 13 | 13 |
| New Orleans | 210 | 246 | 10 | |
| Group: Technical | | | 5 | |
| Subsections: Baton Rouge | | | 9 | |
| Jackson, Miss. | | | 6 | |
| Lake Charles | | | 9 | 39 |
| New York | 4,715 | 4,894 | | |
| Groups: Basic Science | | | 4 | |
| Communication | | | 12 | |
| Illumination | | | 4 | |
| Power and Industrial Division | | | 13 | |
| Subsections: Hudson Valley | | | 6 | |
| New Jersey | | | 14 | 53 |
| Niagara Frontier | 249 | 266 | 9 | 9 |
| Niagara International | 79 | 101 | 12 | 12 |
| North Carolina | 206 | 229 | 2 | |
| Subsections: Charlotte | | | 9 | |
| Mid-State | | | 2 | 13 |
| North Texas | 307 | 385 | 10 | |
| Groups: Communications | | | 1 | |
| Electronics | | | 3 | |
| Industrial Practices | | | 3 | |
| Subsections: Central Texas | | | 5 | |
| Fort Worth | | | 7 | |
| West Central Texas | | | 8 | 37 |
| Oklahoma City | 168 | 180 | 9 | |
| Groups: Communications | | | 4 | |
| Electronics | | | 4 | |
| Industrial and Commercial Practices | | | 3 | |
| Power Systems | | | 4 | 24 |
| Panhandle Plains | 89 | 131 | 9 | 9 |
| Philadelphia | 1,248 | 1,344 | 11 | |
| Groups: Basic Science | | | 3 | |
| Communication | | | 6 | |
| Electronics | | | 3 | |
| Industrial Practices | | | 3 | |
| Instruments and Measurements | | | 3 | |
| Power Systems | | | 3 | |
| Subsection: Wilmington | | | 10 | |
| Wilmington Discussion Group | | | 3 | 45 |
| Pittsburgh | 916 | 1,050 | 7 | |
| Groups: Basic Science | | | 2 | |
| Industry | | | 3 | |
| Power | | | 2 | |
| Subsections: Centre County | | | 8 | |
| Johnstown | | | 6 | 28 |
| Pittsfield | 240 | 283 | 12 | |
| Group: Discussion | | | 6 | 18 |
| Portland (Oreg.) | 407 | 438 | 24 | 24 |
| Providence | 129 | 132 | 9 | 9 |
| Richland | 61 | 94 | 8 | 8 |
| Rochester | 204 | 214 | 16 | |
| Groups: Communication | | | 1 | |
| Power | | | 1 | 18 |
| Rock River Valley | 69 | 84 | 8 | |
| St. Louis | 446 | 521 | 12 | |
| Groups: Electronics | | | 8 | |
| Industrial Power Practices | | | 9 | 29 |
| San Diego | 150 | 157 | 10 | |
| Groups: Electrical Control | | | 4 | |
| Electronics | | | 2 | 16 |
| San Francisco | 1,137 | 1,259 | 9 | |
| Groups: Technical | | | 20 | |
| Subsections: Fresno | | | 10 | |
| Sacramento | | | 10 | |
| San Jose | | | 11 | |
| Shasta | | | 10 | 70 |
| Schenectady | 839 | 928 | 5 | |
| Groups: Basic Science | | | 3 | |
| Electronics | | | 2 | |
| The Engineer in Management | | | 3 | |
| Generation and Transmission | | | 3 | |
| Industrial Power Applications | | | 3 | |
| Transportation | | | 2 | 21 |
| Seattle | 374 | 422 | 11 | |
| Groups: Aircraft | | | 3 | |
| Electronics | | | 3 | |
| Power | | | 6 | 23 |
| Sharon | 158 | 178 | 9 | 9 |
| Shreveport | 65 | 74 | 9 | 9 |
| South Bend | 95 | 102 | 11 | 11 |
| South Carolina | 86 | 122 | 3 | |
| Subsections: Charleston | | | 5 | |
| Columbia | | | 4 | 12 |
| South Texas | 131 | 163 | 11 | |
| Group: Technical | | | 1 | |
| Subsection: Corpus Christi | | | 6 | 18 |
| Spokane | 125 | 128 | 9 | 9 |
| Springfield | 93 | 88 | 17 | |
| Group: Technical | | | 1 | 18 |
| Syracuse | 203 | 237 | 10 | 10 |
| Toledo | 103 | 117 | 7 | 7 |
| Toronto | 509 | 557 | 18 | |
| Groups: Communications | | | 3 | |
| Discussion | | | 7 | |
| Subsections: Hamilton | | | 10 | |
| Niagara | | | 1 | 39 |
| Tulsa | 101 | 139 | 9 | |
| Group: Technical | | | 3 | 12 |
| Urbana | 88 | 99 | 8 | 8 |
| Utah | 110 | 115 | 13 | 13 |
| Vancouver | 167 | 182 | 15 | |
| Group: Electronics | | | 5 | 20 |
| Virginia | 210 | 168 | 4 | |
| Subsections: Hampton Roads | | | 7 | |
| Richmond | | | 3 | |
| Western Virginia | | | 3 | 17 |
| Washington | 790 | 832 | 8 | |
| Groups: Communications | | | 3 | |
| Electrical Research | | | 3 | |
| Electronics | | | 3 | |
| Mathematics | | | 1 | |
| Power | | | 3 | 21 |
| West Virginia | 102 | 120 | 10 | |
| Group: Technical | | | 1 | |
| Subsection: Tri-State | | | 6 | 17 |
| Wichita | 86 | 82 | 11 | 11 |
| Worcester | 81 | 88 | 8 | 8 |
| | 27,527 | 30,460 | | 1,613 |

Total Sections, 85

Total technical groups, 114

Total Subsections, 49

Total attendance, 131,936

### Table II. Branch Meetings Held During Year Ending April 30, 1949

| Branch | Number |
|---|---|
| Akron, University of | 21 |
| Alabama Polytechnic Institute | 3 |
| Alabama, University of | 13 |
| Alberta, University of | 10 |
| Arizona, University of | 38 |
| Arkansas, University of | 21 |
| British Columbia, University of | 28 |
| Brooklyn, Polytechnic Institute of | |
| Day division | 7 |
| Evening division | 7 |
| Brown University | 18 |
| Bucknell University | 10 |
| California Institute of Technology | 12 |
| California, University of | 16 |
| Carnegie Institute of Technology | 26 |
| Case Institute of Technology | 14 |
| Catholic University of America | 8 |
| Cincinnati, University of | 9 |
| Clarkson College of Technology | 11 |
| Clemson Agricultural College | 12 |
| Colorado Agricultural and Mechanical College | 13 |
| Colorado, University of | 14 |
| Columbia University | 3 |
| Connecticut, University of | 8 |
| Cooper Union | |
| Day division | 10 |
| Evening division | 2 |
| Cornell University | 12 |
| Delaware, University of | 7 |
| Denver, University of | 15 |
| Detroit, University of | 6 |
| Drexel Institute of Technology | 6 |
| Duke University | 11 |
| Fenn College | 5 |
| Florida, University of | 15 |
| George Washington University | 8 |
| Georgia Institute of Technology | 6 |
| Harvard University | 5 |
| Idaho, University of | 17 |
| Illinois Institute of Technology | 14 |
| Illinois, University of | 8 |
| Iowa State College | 15 |
| Iowa, University of | 30 |
| Johns Hopkins University | 25 |
| Kansas State College | 7 |

| Branch | Number |
|---|---|
| Kansas, University of | 9 |
| Kentucky, University of | 16 |
| Lafayette College | 9 |
| Lehigh University | 6 |
| Louisiana State University | 13 |
| Louisiana Polytechnic Institute | 5 |
| Louisville, University of | 12 |
| Maine, University of | 9 |
| Manhattan College | 8 |
| Marquette University | 12 |
| Maryland, University of | 9 |
| Massachusetts Institute of Technology | 13 |
| Michigan College of Mining and Technology | 8 |
| Michigan State College | 2 |
| Michigan, University of | 10 |
| Milwaukee School of Engineering | 10 |
| Minnesota, University of | 1 |
| Mississippi State College | 9 |
| Missouri School of Mines and Technology | 9 |
| Missouri, University of | 6 |
| Montana State College | 7 |
| Nebraska, University of | 10 |
| Nevada, University of | 15 |
| Newark College of Engineering | 9 |
| New Hampshire, University of | 10 |
| New Mexico State College | 11 |
| New Mexico, University of | 5 |
| New York, College of the City of | |
| Day division | 16 |
| Evening division | 00 |
| New York University | |
| Day division | 28 |
| Evening division | 6 |
| North Carolina State College | 11 |
| North Dakota State Agricultural College | 5 |
| North Dakota, University of | 13 |
| Northeastern University | 19 |
| Northwestern University | 15 |
| Norwich University | 00 |
| Notre Dame, University of | 10 |
| Ohio Northern University | 18 |
| Ohio State University | 12 |
| Ohio University | 7 |
| Oklahoma Agricultural and Mechanical College | 9 |
| Oklahoma, University of | 10 |
| Oregon State College | 5 |
| Pennsylvania State College | 12 |

| Branch | Number |
|---|---|
| Pennsylvania, University of | 9 |
| Pittsburgh, University of | 29 |
| Pratt Institute | 10 |
| Princeton University | 8 |
| Puerto Rico, University of | 00 |
| Purdue University | 14 |
| Rensselaer Polytechnic Institute | 3 |
| Rhode Island State College | 4 |
| Rice Institute | 7 |
| Rose Polytechnic Institute | 10 |
| Rutgers University | 6 |
| Santa Clara, University of | 7 |
| South Carolina, University of | 9 |
| South Dakota School of Mines and Technology | 5 |
| South Dakota State College | 9 |
| Southern California, University of | 12 |
| Southern Methodist University | 14 |
| Stanford University | 8 |
| Stevens Institute of Technology | 00 |
| Swarthmore College | 10 |
| Syracuse University | 5 |
| Tennessee, University of | 11 |
| Texas Agricultural and Mechanical College | 6 |
| Texas Technological College | 14 |
| Texas, University of | 18 |
| Toronto, University of | 3 |
| Tufts College | 15 |
| Tulane University | 5 |
| Union College | 10 |
| Utah, University of | 9 |
| Vanderbilt University | 8 |
| Vermont, University of | 13 |
| Villanova College | 13 |
| Virginia Military Institute | 13 |
| Virginia Polytechnic Institute | 16 |
| Virginia, University of | 8 |
| Washington State College | 15 |
| Washington, University of | 10 |
| Washington University | 8 |
| Wayne University | 8 |
| West Virginia University | 5 |
| Wisconsin, University of | 8 |
| Worcester Polytechnic Institute | 8 |
| Wyoming, University of | 10 |
| Yale University | 7 |
| Total Branches, 129 | 1,405 |

### Table III. Section Meetings Held During Last Three Fiscal Years

| | Fiscal Year Ending April 30 | | |
|---|---|---|---|
| | 1947 | 1948 | 1949 |
| Number of Sections | 75 | 81 | 85 |
| Number of meetings held | 1,370 | 1,463 | 1,613 |
| Average number of meetings | 18 | 18 | 19 |
| Total attendance | 154,943 | 119,943 | 131,936 |
| Average attendance per meeting | 113 | 82 | 82 |

### Table IV. Branch Meetings Held During Last Three Fiscal Years

| | Fiscal Year Ending April 30 | | |
|---|---|---|---|
| | 1947 | 1948 | 1949 |
| Number of Branches | 126 | 127 | 129 |
| Number of meetings held | 1,031 | 1,233 | 1,405 |
| Average number of meetings | 8 | 10 | 11 |
| Total attendance | 61,026 | 77,224 | 105,290 |
| Average attendance per meeting | 59 | 63 | 75 |

# AIEE PERSONALITIES .....

**O. B. Blackwell** (A '08, F '17, Member-for-Life) has retired from his position as Assistant Vice-President of the American Telephone and Telegraph Company, New York, N. Y. A 43-year veteran of the Bell System, Mr. Blackwell joined the Transmission and Protection Division of American Telephone and Telegraph Engineering Department in Boston, Mass., shortly after acquiring his bachelor of science degree in electrical engineering from the Massachusetts Institute of Technology in 1906. In 1914, he was placed in charge of the department. When the Department of Development and Research was organized in 1919, he became Transmission Development Engineer. In 1934, when this department was consolidated with the Bell Laboratories, Mr. Blackwell was appointed Director of Transmission Development. The following year, he was named Manager of Staff Departments, and in 1937 he became a Vice-President. Mr. Blackwell returned to the American Telephone and Telegraph Company in 1944 as an Assistant Vice-President. Holder of a number of patents in the communication field, he is a member of the Acoustical Society, the American Physical Society, the American Association for the Advancement of Science, and the Institute of Radio Engineers. Mr. Blackwell who has been active in AIEE, most recently served on the Finance Committee, the Headquarters Committee, and the Lamme Medal Committee. A native of Bourne, Mass., he was born August 21, 1884.

**O. B. Blackwell**

**C. R. Hanna** (A '24, F '44), Associate Director of the Research Laboratories, Westinghouse Electric Corporation, Pittsburgh, Pa., has been awarded the Howard N. Potts Medal of the Franklin Institute. The award is being given in recognition of Dr. Hanna's initiative in the conception and development of the Tank Gun Stabilizer. This device helps attain accuracy of fire while a tank is in motion on rough terrain and secures a greater number of aimed hits than were formerly possible. The invention won for Dr. Hanna a Presidential Citation in 1942. In the long list of Dr. Hanna's achievements is included design of the Silverstat, an automatic voltage regulator first used for control of generators and used since 1938 on motors, turbines, or any place where automatic voltage control is required. He directed development of the Westinghouse Photophone, one of the first successful methods of producing sound motion pictures. Dr. Hanna, a native of Indianapolis, Ind., received his bachelor's degree in electrical engineering from Purdue University in 1922. In 1926, Purdue awarded him the professional electrical engineer degree, and, in 1945, an honorary doctor of engineering degree. Entering the Westinghouse Corporation in 1922, he was active in the development of loud-speakers and sound motion picture apparatus until 1930. He was then made manager of the Development Division of the Research Department, becoming Manager of the Electro-Mechanical Division in the same department in 1936. He has held his present post since 1944.

**R. A. Hopkins** (A '19, M '35), Supervisor of Central Station and Transportation Sales for the Los Angeles (Calif.) area of the Westinghouse Electric Corporation has been awarded the Westinghouse Order of Merit. Mr. Hopkins, Vice-President of AIEE District 8, joined the company as a student apprentice. In 1910, he was transferred to the company's Los Angeles office as a salesman where he specialized largely in engineering and sales work with the petroleum industry in southern California. Later he transferred his activities to central station and transportation engineering and sales activities and, in 1924, was made supervisor for the Los Angeles area, a position he still holds. In 1923–24, he served as Secretary of the Los Angeles Section, and from 1925 to 1926 was Chairman of the Section. During his many years in Los Angeles, Mr. Hopkins has also been active in other professional organizations. He has held membership in the Los Angeles Engineering Council of Founder Societies since 1945, and served as President of that organization in 1947–48. A member of the Los Angeles Electric Club, he headed that organization as President in 1936–37. He has been a member of the Pacific Coast Electrical Association since 1921, and in 1944–45 served on that group's Board of Directors.

**Hendley Blackmon** (M '32) Managing Editor of *Electrical World* since 1947, has been appointed Assistant Manager of Engineering Association Activities for the Westinghouse Electric Corporation. He will be headquartered at the East Pittsburgh (Pa.) works. Mr. Blackmon will work with Westinghouse engineers in the preparation of papers to be presented before engineering associations. Following his graduation from Georgia School of Technology in 1925 with a bachelor of science degree in electrical engineering, Mr. Blackmon spent a year on the Westinghouse student course. Then, he went to the Switchboard Engineering Department. He moved to the General Engineering Department in 1928 and in 1932 was named Technical Editor of the company's Technical Press Bureau. He was appointed Manager in 1938, a position he held until 1945 when he resigned to join the McGraw-Hill Publishing Company, New York, N. Y., as Electrical Editor of *Product Engineering*. In 1946 he was made Managing Editor of *Product Engineering* and a year later was appointed Managing Editor of *Electrical World*.

**Hendley Blackmon**

**G. R. Town** (A '28, M '37), formerly Manager of Engineering and Research and Assistant Secretary of the Stromberg-Carlson Company, Rochester, N. Y., has been named Professor of Electrical Engineering and Associate Director of the Engineering Experiment Station, Iowa State College, Ames. Dr. Town received an electrical engineering degree from Rensselaer Polytechnic Institute in 1926, and the doctor of engineering degree there in 1929. He was employed by Leeds and Northrup Company, Philadelphia, Pa., and the Arma Engineering Company, Brooklyn, N. Y., until 1933 when he returned to Rensselaer to become instructor in mathematics and later to teach electrical engineering. In 1936, he joined Stromberg-Carlson as engineer in the company's research laboratory. He became successively Engineer-in-Charge of the Television Laboratory and Assistant Director of Research before assuming the duties he left when he joined the Iowa State faculty.

**F. E. Crever** (A '27, M '45) has been named Division Engineer, Control Systems Division, in the General Electric Company's General Engineering and Consulting Laboratory at Schenectady, N. Y. Mr. Crever joined General Electric in 1926, after receiving degrees in mechanical and electrical engineering from Stanford University. Appointed Assistant Engineer of the Control Systems Division at the same time was **G. A. Hoyt** (M '48). Formerly a section engineer in the division, he joined the company after graduating in 1941 from Kansas State College.

**E. C. Whitney** (A '36, M '45) has been named Manager of the Large Salient-Pole Generator Section, A-C Engineering Department, Transportation and Generator Division, Westinghouse Electric Corporation, East Pittsburgh, Pa. Mr. Whitney has been with Westinghouse since his graduation in 1935.

**L. C. Shackelford** (A '42) has been named a Wire and Cable Specialist in the Construction Materials Department of the General Electric Company. His headquarters will be in Seattle, Wash. With General Electric since 1941, Mr. Shackelford previously was in the Government and Transportation Quotations Section.

**F. W. Russell** (A '26), General Superintendent of the Louisville (Ky.) Gas and Electric Company for the last several months, has been elected Vice-President in Charge of Operations. With the company for 24 years, he succeeds the late **A. W. Lee** (M '40).

**C. F. Myers** (A '31, M '42), formerly Engineer in Charge of Overhead Construction, Puget Sound Power and Light Company, Seattle, Wash., has joined the Electric Bond and Share Company. Replacing him at the Seattle utility is **Lawrence Palmer** (A '45), who previously was Associate Engineer.

**R. L. Schacht** (A '44), formerly General Superintendent and Acting General Manager has been appointed General Manager of the Consumers Public Power District, Columbus, Neb. Mr. Schacht has a background of 26 years of continuous utility operation and engineering in Nebraska.

**K. T. Compton** (F '31), Chairman of the Research and Development Board of the National Military Establishment and Chairman of the Corporation of the Massachusetts Institute of Technology has been elected a director of the McGraw-Hill Publishing Company, New York, N. Y.

**R. C. Blatt** (M '39) recently became Associate Editor of *Electrical World*, New York, N. Y. Formerly editor of *Aviation Maintenance and Operations* and *Airports and Air Carriers*, he is a graduate electrical engineer with nearly 20 years of practical experience in the field.

**R. D. Teasdale** (A '46) has been named Professor in the School of Electrical Engineering, Georgia Institute of Technology. Recently, he received a doctor of philosophy degree from the Illinois Institute of Technology, where he had done part-time teaching.

**Wright Canfield** (A '31, M '38), formerly Assistant to the President, has been elected a vice-president of the Public Service Company of Oklahoma, Tulsa. Joining the company in 1930, he was named Assistant to the President in 1945.

**C. W. Wood** (A '42), until recently Chief Engineer for Jet-Heat Inc., New York, N. Y., has joined the Standard-Thomson Corporation, automotive and aviation parts manufacturer, Dayton, Ohio, as a design engineer.

**L. R. Crane** (A '41, M '48), former Engineering Specialist, is now Manager of Switchgear and Protective Devices Sales, A. B. Chance Company, Centralia, Mo. He joined the company as a sales engineer in 1947.

**L. R. Patterson** (A '30, M '41), formerly Staff Engineer, Electric Operations, has been named Superintendent, Electric System Planning, by the Public Service Company of Colorado, Denver. He joined the organization in 1923.

**L. N. McClellan** (A '14, F '38), Chief Engineer, United States Bureau of Reclamation, Denver, Colo., has been awarded the honorary degree of doctor of engineering by the University of Colorado, Boulder. He served as Vice-President of the Institute, 1937–39.

**J. W. Carpenter** (M '35, F '46) has been named Chairman of the Board, Texas Power and Light Company, Dallas. He has been General Manager of the utility for 30 years and President and General Manager for 22 years.

**J. E. Shepherd** (M '44), Engineering Director for electron tubes at the Sperry Gyroscope Company, Great Neck, N. Y., recently became President of the Technical Societies Council of New York Inc., for the term 1949–50.

**J. C. Hess, Jr.,** (M '40), has been made Vice-President in Charge of Production at the Leeds and Northrup Company, Philadelphia, Pa. Formerly, Assistant Factory Manager of the Germantown plant, Mr. Hess has been with the organization for 33 years.

**E. J. Karsten** (A '26, M '37), formerly Supervising Electrical Engineer, United Light and Power Service Company, Davenport, Iowa, has joined Kansas Gas and Electric Company Wichita, as Chief Engineer.

**J. E. Thomas** (A '16, M '27) has been named Chief Engineer of Power Plants for the West Penn Power Company at Pittsburgh, Pa. Mr. Thomas is a 40-year veteran of the West Penn organization.

**Robert Anderson** (A '40, M' 49), formerly on the faculty of the University of New Hampshire, Durham, has been appointed Assistant Professor of Electrical Engineering at the Newark (N. J.) College of Engineering.

**R. D. Ingalls** (M '44), until recently Assistant Chief Engineer, has been promoted to Chief Engineer of the Diehl Manufacturing Company, Somerville, N. J.

**G. I. Cohn** (A '43), an instructor in electrical engineering at the Illinois Institute of Technology, Chicago, has been made an assistant professor.

**J. C. Atkins** (A '47) has been appointed Heating Industry Specialist for Cutler-Hammer, Inc., Milwaukee, Wis.

# OBITUARY

**William Myles Howard Ballantyne** (A '21, M '44), Inspection Engineer for the Pennsylvania Water and Power Company, Baltimore, Md., died August 29, 1949. Born in Glasgow, Scotland, September 25, 1886, Mr. Ballantyne attended Dumfries Academy and the Technical College of the same city. After a short period of employment with Kelvin and James White, Limited, in Glasgow and Everett Edgecomb and Company, Limited, in London, England, he went to Canada in 1910 and took a position with the Canadian General Electric Company. One year later, he became identified with the Pennsylvania Water and Power Company as an electrical inspector at the Holtwood hydroelectric plant on the Susquehanna River. In 1920, he was designated Maintenance Assistant to the Superintendent of Substations, becoming Installation Engineer in 1923. When the Safe Harbor hydroelectric development was started, he was named Chief Inspector of the Safe Harbor Water Power Corporation, also in Baltimore. After four years in that post, he was appointed Engineer for the Pennsylvania Water and Power Company and the Safe Harbor Water Power Corporation. During the early part of World War II, he acted as technical consultant for The Eastern Rolling Mill Company of Baltimore in connection with the installation and operation of equipment for manufacturing munitions. Mr. Ballantyne was a member of the American Welding Society and also was a member of the Engineers Club of Baltimore.

**William H. Lawrence** (A '99, M '12, Member-for-Life), who retired in 1937 as Chief Operating Engineer of the Consolidated Edison Company of New York (N. Y.), Inc., died August 8, 1949. Born in Middletown, Ohio, February 28, 1870, his first position was with the General Electric Company, Schenectady, N. Y. Subsequently, he joined the Edison Manufacturing Company, New York, N. Y., serving as Assistant Superintendent of Construction in the western offices of that company in Cincinnati, Ohio. He continued in that post after the consolidation of the Edison and Thomson-Houston Companies with the Central Thomson-Houston Company. In 1889 Mr. Lawrence became associated with the Edison Electric Illuminating Company of New York (N. Y.), predecessor of Consolidated Edison. Three years after joining the utility, he became an assistant superintendent in the operating department and, soon after, superintendent. Later, he became Superintendent of the New York Edison Company's (also a predecessor of Consolidated) Waterside electric generating station and was named Chief Operating Engineer in 1926. Six years thereafter, he was appointed to this position for both New York Edison and the United Electric Light and Power Companies. Mr. Lawrence was a member of the Power Stations Committee from 1920 to 1924 and the Power Generation Committee from 1924 to 1929. He belonged to the American Society of Mechanical Engineers, the New York Electrical Society, and the Edison Pioneers.

**Frederik Borch** (A '08, M '28, F '39, Member-for-Life), Head of the Electrical Engineering Department, Cleveland (Ohio) Electric Illuminating Company, on his retirement in 1945, died August 15, 1949. Born in Kolding, Denmark, August 9, 1878, he came to the United States in 1905, soon after graduating from the Electrotechnical Institute of Mittweida, Saxony, Germany. Previously, he had attended the University of Copenhagen and the Polytechnical Institute of Copenhagen. He joined the New York (N. Y.) Edison Company in 1906 and remained there until 1918, working as a draftsman for two years and a division head in charge of substation design for ten years. His next position was with the Ohio Edison Company, Akron, where he was Electrical Engineer in Charge of Station Design and Supervisor of Construction. In 1920, he did consulting engineering work in Cleveland and the following year he became associated with the Cleveland Electric Illuminating Company. Named Senior Electrical Engineer in 1923, Mr. Borch advanced to Assistant Superintendent of the Engineering Department in 1937, and became Head of the Electrical Engineering Department in 1942.

**Ross Strawn Wallace** (A '44, Member-for-Life), on the Board of Directors of the Central Ill. Light Company, Peoria, and former President and Chairman of the Board, died August 28, 1949. A native of Chatsworth, Illinois, born December 9, 1869, Mr. Ross had been with the Central Illinois Light Company and its predecessor, the Peoria Gas and Electric Company, since 1900. From Department Superintendent in 1903, he rose to the post of Vice-President and General Manager, and then became President in 1933. Subsequently, he was named Chairman of the Board, from which post he retired in 1947. A mechanical engineering alumnus of the University of Illinois, graduated in 1891, Mr. Ross' early business experience was obtained with A. L. Ide and Sons of Springfield, Ill. His next position, which he held before going to Peoria, was as electrical and mechanical engineer for the Board of Managers of the Illinois State Reformatory, where he was in charge of remodeling and enlarging equipment at the institution.

**Frank C. Watson** (M '23), Works Engineer International Nickel Company, Huntington, W. Va., died September 2, 1949. A native of Eugene, Ind., he was born March 19, 1884. After graduating from Purdue University in 1904 with a bachelor of science degree in electrical engineering, he went to work for the N and W Railway in Roanoke, Va., as an electrical foreman. Remaining there for five years, he next joined the C and O Railway in Huntington, his designation being that of Chief Electrician. In 1921, he became associated with the International Nickel Company, his first position there being that of Electrical Superintendent. He was identified with International Nickel until the time of his death.

# MEMBERSHIP • • • •

## Recommended for Transfer

The board of examiners at its meeting of September 15, 1949, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

### To Grade of Fellow

Bankus, J., chief engr., Portland General Elec. Co., Portland, Oreg.
Bany, H., genl. engg. staff asst., switchgear div., General Elec. Co., Phila., Pa.
Beckwith, S., engr.-in-chg., alternating current design, Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Birckhead, L., elec. engr., Consolidated Gas Elec. Lt. & Pr. Co. of Baltimore, Baltimore, Md.
Blackmon, H. N., managing editor, *Electrical World*, McGraw-Hill Pub. Co., New York, N. Y.
Conrad, A. G., prof. & chmn., dept. of elec. engg., Yale Univ., New Haven, Conn.
DeBlieux, E. V., asst. to div. engr., General Elec. Co., Pittsfield, Mass.
Diehl, G. S., supt. of oper., Pennsylvania Water & Pr. Co. & Safe Harbor Water Pr. Corp., Lancaster, Pa.
Dovjikov, A., elec. engr. P-5; head analysis & research sec., Bonneville Pr. Adms., Portland, Oreg.
Flanigen, J. M., plant engr., Georgia Pr. Co., Atlanta, Ga.
Gilson, W. J., pres., Eastern Pr. Devices Ltd., Toronto, Ontario, Canada
Jolliffe, J. P., chief, branch of operations, Bonneville Pr. Adms., Portland, Oreg.
McCune, F. K., asst. to genl. mgr., apparatus dept., General Elec. Co., Schenectady, N. Y.
Mellett, J. E., pres., J. M. Clayton Co., Atlanta, Ga.
Schnure, F. O., supt. elec. dept., Bethlehem Steel Co., Sparrows Point, Md.

15 to grade of Fellow

### To Grade of Member

Baird, J., assoc. prof., Univ. of Wisconsin, Madison, Wis.
Bates, F. C., elec. engr., Fischbach & Moore, Inc., of Calif.; owner, Bates Engineering, Salt Lake City, Utah
Beach, J. M., bldg. & equipment engr., Northwestern Bell Tel. Co., Minneapolis, Minn.
Blumberg, L., head, engg. school; chmn. elec. & mech. engg. depts., Pennsylvania Military College, Chester, Pa.
Bostonian, E. T., ind. equipment specialist, General Elec. Supply Corp., New York, N. Y.
Buchan, R. L., electrical operating engr., Union Elec. Pr. Co., St. Louis, Mo.
Camp, P. L., application engr., General Elec. Co., Phila., Pa.
Caress, A. E., senior engr., Eastman Kodak Co., Rochester, N. Y.
Carter, B. H., field engr., Rural Elec. Adms., Washington, D. C.
Chiang, F. Y., elec. engr., Sung Sing Cotton Mill #9 Shanghai, China; (temporarily General Elec. Co., U.S.A.)
Duyan, P., Jr., asst. equipment engr., Douglas Aircraft Co., Inc., Santa Monica, Calif.
Edwards, E. A., design engr., Eastman Kodak Co., Rochester, N. Y.
Eschbach, D. O., consulting elec. engr., Gilbert Associates, Inc., Reading, Pa.
Ferguson, S. A., assoc. prof. elec. engg., Univ. of South Carolina, Columbia, S. C.
Fincher, E. H., control engr., Westinghouse Elec. Corp., Los Angeles, Calif.
Fitzgerald, D. J., asst. purchasing agent, Consolidated Gas Elec. Lt. & Pr. Co., of Baltimore, Md.
Godwin, G. L., engr., Westinghouse Elec. Corp., E Pittsburgh, Pa.
Goldberg, Y., underground design engr., Iowa Pr. & Lt. Co., Des Moines, Iowa
Golembe, S. N., senior engr., Laboratory for Electronics, Inc., Boston, Mass.
Hanville, S. H., Jr., head, aircraft electrical pr. sec., Bureau of Aeronautics, Washington, D. C.
Hogan, A. W., elec. engr. P-5, Naval Ordnance Lab., Silver Spring, Md.
Holt, G. A., instrument engr., Oak Ridge National Lab., Oak Ridge, Tenn.
Jaberg, H. A., pres.-mgr. chief elec. inspector, Inspection Bureau, Inc., Cincinnati, Ohio
Johns, S. M., mgr., Los Angeles Office, Westinghouse Elec. Corp., Los Angeles, Calif.
Johnson, F. F., asst. prof. elec. engg., Univ. of Houston, Houston, Tex.
Kelly, J. A., elec. designer-drafting, General Elec. Co., Phila., Pa.
Kern, K. C., elec. engr., The Baltimore Transit Co., Baltimore, Md.
Killin, A. M., asst. supt., carbide div., electro metallurgical div., Union Carbide & Carbon Corp., Niagara Falls, N. Y.
Klauber, P. M., engr., Solar Aircraft Co., San Diego, Calif.
Laidlaw, D. A., asst. elec. distribution supt., Consumers Power Co., Kalamazoo, Mich.
Lay, C. R., senior engr., Indiana & Michigan Electric Co., Marion, Ind.
Linder, F. W., chief elec. engr., Dairyland Power Cooperative, LaCrosse, Wis.
Lomholt, C., apparatus design engr., Federal Tel. & Radio Corp., Clifton, N. J.
Melcher, J. C., field engr., Leeds & Northrup Co., Boston, Mass.
Nelson, R. A., test engr., Simplex Wire & Cable Co., Chicago, Ill.
Oberholtzer, J. R., distribution engr., Commonwealth & Southern Corp., Jackson, Mich.
O'Gara, E. H., supt., San Diego service shop, General Elec. Co., Phoenix, Ariz.
Osborne, W. S., asst. to supervisor, Atlantic Refining Co., Philadelphia, Pa.
Peterson, H. O., elec. engr., F. H. McGraw & Co., Pittsburgh, Pa.
Sargeant, G. H., Jr., operating engr., Burns & Roe, Inc., New York, N. Y.
Scarborough, F. L., elec. engr. IV, Tennessee Valley Authority, Chattanooga, Tenn.
Shuey, R. L., engr. & student, radiation lab., Univ. of California, Berkeley, Calif.
Simpson, J. W., supervisory engr., switchgear div., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Soria, R. M., director of research, American Phenolic Corp., Chicago, Ill.
Specht, T. R., design engr., Westinghouse Elec. Corp., Sharon, Pa.
Srinivasan, A., prof. college of engg., Univ. of Madras, India
Stafford, D. E., chief engr., National Elec. Coil Co., Columbus, Ohio
Stair, J., Jr., elec. engr., Pennsylvania RR., Philadelphia, Pa.
Teague, T. S., section leader, General Elec. Co., Schenectady, N. Y.
Unangst, G. W., asst. meter & service supt., Ohio Power Co., Zanesville, Ohio
VanAllen, R. C., field engr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Wagner, E. J., asst. prof., Illinois Inst. of Tech., Chicago, Ill.
Weinfield, B. S., supervisor, General Elec. Co., Philadelphia, Pa.
Williamson, J. W., development engr., tocco div., The Cleveland Crankshaft Co., Cleveland, Ohio
Winckowski, B. F., elec. engr., National Advisory Comm. for Aeronautics, Langley Air Force Base, Va.
Wirz, A. T. A., designer & load supervisor, Buffalo Niagara Elec. Corp., Buffalo, N. Y.
Wynn, R. S., prof. elec. engg., Louisiana Polytechnic Inst., Ruston, La.

57 to grade of Member

## Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before November 25, 1949, or January 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

### To Grade of Fellow

de Koning, T., 4843 Griscom St., Philadelphia, Pa.

1 to grade of Fellow

### To Grade of Member

Byerlay, H. L., Lawrence Inst. of Technology, Detroit, Mich.
Carter, T. N., Cameron Machine Co., Brooklyn, N. Y.
Chin, P. H., Central Technical, Inc., New York, N. Y.
Cook, V. M., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Cross, C., Phillips Petroleum Co., Phillips, Tex.
Dutt, S. C., General Elec. Co., Erie, Pa.
Eichenberger, O. R., Consumers Power Co., Jackson, Mich.
Evirs, H. W., Boston Edison Co., Boston, Mass.
Fox, W. C. O., Thornycroft Apt., Scarsdale, N. Y.
Griest, R. H., Hughes Aircraft Co., Culver City, Calif.
Marsh, J., Marsh Elec. Motor Shop, Prescott, Ariz.
Mattox, R. P., Parsons-Aerojet Co., Los Angeles, Calif.
Moore, L. N., Bell Tel. Co. of Canada, Ottawa, Ontario, Canada
Powley, G. R., Virginia Polytechnic Inst., Blacksburg, Va.
Quinn, M. L., Sinclair Coal Co., St. Louis, Mo.
Reising, C. A., Jr., Hughes Aircraft Co., Culver City, Calif.
Roberts, H. P., Sverdrup & Parcel, Inc., St. Louis, Mo.
Thomas, L. R., Atchison, Topeka & Santa Fe Ry. Co., Chicago, Ill.
Upton, A. P., Minneapolis-Honeywell Reg. Co., Minneapolis, Minn.
Vander Els, B , Bell Tel. Labs., New York, N. Y.
Wicks, S. T., The Crompton Eng. Co. (Madras), Ltd., Madras, India
Yerk, R. G., Hughes Brothers Inc., Seward, Nebr.

22 to grade of Member

### To Grade of Associate

**United States, Canada, and Mexico**

1. North Eastern

Brown, V. C., General Elec. Co., Lynn, Mass.
Crapo, A. C., Stone & Webster Engg. Corp., Boston, Mass.
Flowers, E. L., 1104 Park Square Bldg., Boston, Mass.
Fouts, J. M., N. Y. Tel. Co., Buffalo, N. Y.
Goodwin, E. B., Rhode Island State Coll., Kingston, R. I.
Haas, R. S., Rhode Island State Coll., Kingston, R. I.
Hart, G., General Elec. Co., Pittsfield, Mass.
Hawkins, G. E., Hixon Elec. Co., South Boston, Mass.
Jones, L., General Elec. Co., Schenectady, N. Y.
Knackstedt, G., General Elec. Co., Schenectady, N. Y.
Nelson, J. A., General Elec. Co., Schenectady, N. Y.
Pickering, D. L., General Elec. Co., Schenectady, N. Y.
Pletenik, A., General Elec. Co., Schenectady, N. Y.
Salisbury, W. B., Altmar, N. Y.
Sandman, R. L., Sandman Elec. Co., Boston, Mass.
Schultheis, A., Central N. Y. Power Corp., Syracuse, N. Y.
Shockley, B. J., General Elec., Schenectady, N. Y.
Siman, M., Eastman Kodak Co., Rochester, N. Y.
Stelzenmuller, B. E., General Elec. Co., Pittsfield, Mass.
Sternick, S. H., Tobe Deutschmann Corp., Norwood, Mass.
Twardzik, R. J., General Elec. Co., Schenectady, N. Y.
Warner, R. C., Metropolitan Transit Authority, Boston, Mass.
Warnock, F. E., Jr., General Elec. Co., W. Lynn, Mass.

2. Middle Eastern

Agarwal, P. D., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Babyak, W. J., Jones & Laughlin Steel Corp., Pittsburgh, Pa.
Beck, J. C., Ohio Power Co., Bellaire, Ohio
Bevan, C. J., Bethlehem Steel Co., Sparrows Point, Md.
Binkley, H. A., The Dayton Power & Light Co., Sidney, Ohio
Bixby, H. D., Battelle Memorial Inst., Columbus, Ohio
Blitz, M., Natl. Bureau of Standards, Washington, D. C.
Blumenfeld, I. D., 1826 Coventry Rd., Cleveland Heights, Ohio
Boyko, M., Aluminum Co. of America, Cleveland, Ohio
Brandon, F. W., West Penn Power Co., Pittsburgh, Pa.
Chapman, C. B., Jr., Elec. Controller & Mfg. Co., Cleveland, Ohio
Cohen, H. S., N. Y. Shipbuilding Corp., Camden, N. J.
Conrad, H. A., The Ohio Bell Tel. Co., Cleveland, Ohio
Cooper, R. E., The Eastern Shore Public Service Co. of Md., Salisbury, Md.
Cottrill, J. G., 6507 Central Ave., Maryland Park, Md.
Daroff, M. A., U.S.N. Air Development Centre, Johnsville, Pa.
Earley, F. T., General Elec. Co., Washington, D. C.
Fanu, N. M., Westinghouse Elec. Corp., Sharon, Pa.
Ferch, B. C., Strong Elec. Corp., Toledo, Ohio
Fertig, W. C., Jr., N.A.C.A., Municipal Airport, Cleveland, Ohio
Fot, C. J., Guyan Machinery Co., Logan, W. Va.
Grim, E. P., Dept. of Public Safety, Philadelphia, Pa.
Herr, A. C., NACA Lewis Flight Propulsion Lab., Cleveland, Ohio
Hesner, C. J., Elec. Service Mfg. Co., Philadelphia, Pa.
Hively, R. H., Appalachian Elec. Power Co., Charleston, W. Va.
Hood, F. J., General Industries, Inc., Philadelphia, Pa.
Johnson, B. L., General Elec. Co., Erie, Pa.
Karle, R. O., Pennsylvania Tel. Corp., Erie, Pa.
Keim, S. D., Navy Dept., Washington, D. C.
Kinginger, J. H., 333 Broadway, Bangor, Pa.
Knight, W. H., General Elec. Co., Erie, Pa.
Kovacs, S. J., Philadelphia Elec. Co., Philadelphia, Pa.
Lichtenfels, J. L., U.S.N. Air Development Sta., Johnsville, Pa.
Maierson, A. T., Battelle Memorial Inst., Columbus, Ohio
Mansberg, G., David Taylor Model Basin Washington, D. C.
McCabe, B., Lafayette College, Easton, Pa.
McGirk, D. M., 3355—16th St. N. W., Washington, D. C.
Merchant, R. H., N. Y. Shipbuilding Corp., Camden N. J.
Misialek, R. F., NBTL, Philadelphia, Pa.
Mitchell, C. A., Jr., Elec. Controller & Mfg. Co. Cleveland, Ohio
Myers, K. I., York Springs, Pa.
Ostanek, A. J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Patterson, T. T., Jr., Molded Insulation Co., Philadelphia, Pa.
Peebles, E. L., General Elec. Co., Erie, Pa.
Pfirsch, R. J., Lima Elec. Prod. Inc., Lima, Ohio
Povejsil, D. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Pryce, J. D., Carnegie Illinois Steel Corp., Johnstown, Pa.
Rabek, N. J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Richards, R. L., Delaware Power & Light Co., Wilmington, Del.
Russo, H. L., Univ. of Pittsburgh, Pittsburgh, Pa.
Stoker, C. W., Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
Stoudenmire, J. H., Bendix Aviation Corp., Towson, Md.
Thornburg, H. S., R. E. Uptegraff Mfg. Co., Scottdale. Pa.
Triolo, J. P., N.A.D.S., Johnsville, Pa.
Troutman, W. E. (re-election), Philadelphia Elec. Co., Philadelphia, Pa.
Vanica, H. R., The Ohio Bell Tel. Co., Akron, Ohio
Wardrop, G. O., Carbide & Carbon Chem. Corp., South Charleston, W. Va.
Warrick, T. J., General Elec. Co., Erie, Pa.
Weber, P. J., Westinghouse Elec. Corp., Lima, Ohio
White, T. R., General Elec. Co., Baltimore, Md.
Williams, J. W., The Eastern Shore Public Service Co., Salisbury, Md.
Winkle, D. E., The Austin Co., Cleveland, Ohio

3. New York City

Anello, M. T., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.

Bartoletti, C., 2821 Briggs Ave., Bronx, New York, N. Y.
Bonem, E. J., Atlantic Electronics Corp., Port Washington, N. Y.
Cadden, J. V., G & W Elec. Specialty Co., New York, N. Y.
Chen, S. M., Polytech. Inst. of Brooklyn, Brooklyn, N. Y.
Connelly, J. F., Board of Transportation, New York, N. Y.
Dagnall, C. H., Jr., Bell Tel. Labs., New York, N. Y.
Dye, J. W., Jr., Long Island Lighting Co., Roslyn, N. Y.
Eland, P., W. L. Maxson Corp., New York, N. Y.
Frank, R. J., EBASCO Services, New York, N. Y.
Gore, J. H., Devenco, Inc., New York, N. Y.
Gumaer, H., Gaveco Labs., Inc., New York, N. Y.
Heyd, R. L., Jr., 315 E. 24th St., New York, N. Y.
Howitt, G., Alan B. DuMont Labs., E. Paterson, N. J.
Johnson, V. L., Federal Telecommunication Labs., Nutley, N. J.
Leopold, G. R., Bell Tel. Labs., Inc., Murray Hill, N. J.
Lerner, T., 105 Pinehurst Ave., New York, N. Y.
Lucas, A. J., Dept. of Public Works, New York, N. Y.
Markey, J. P., J. G. White Engg. Corp., New York, N. Y.
Merrian, M. M., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Morrison, C. G., Bell Tel. Labs., New York, N. Y.
Mueller, G. H., L. I. Lighting Co., Garden City, N. Y.
Piazza, G. A., Westinghouse International, New York, N. Y.
Pirow, J., L. I. Lighting Co., Mineola, N. Y.
Rasmussen, L. C., Public Service Elec. & Gas Co., Newark, N. J.
Reichenstein, H. W., Port of N. Y. Authority, New York, N. Y.
Samson, G. C., Sperry Gyroscope Co., Great Neck, L. I., N. Y.
Soller, A. F., General Elec. Co., New York, N. Y.
Soos, L. L., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Sorensen, T., Consolidated Edison Co. of N. Y., New York, N. Y.
Stanton, G. V., Federal Tel. & Radio Corp., Clifton, N. J.
Trinkaus, B. B., Bendix Aviation Corp., Teterboro, N. J.
Webster, R. H., T. Frederick Jackson, Inc., New York, N. Y.
Ziblatt, R., 77–41 250th St., Bellerose, N. Y.

4. Southern

Barnette, P. J., Jr., Homer, La.
Bonner, D. G., Southwestern Gas & Elec. Co., Shreveport, La.
Butt, L. R., Fla. Power & Light Co., Fort Pierce, Fla.
Caudle, J. M., TVA, Chattanooga, Tenn.
Chavis, C. L., TVA, Wilson Dam, Florence, Ala.
Dyson, L. M., Louisiana Polytechnic Inst., Ruston, La.
Faucheux, N. P., Louisiana Power & Light Co., Sterlington, La.
Fike, J. W., Box 445, Northport, Ala.
Jester, A. H., Jr., 105 Wilson St., Greenwood, S. C.
Mayes, T. L., Jr., Winchester, Tenn.
McCormick, P. S., Alabama Power Co., Mobile, Ala.
Meacham, H. P., Jr., Duke Power Co., Charlotte, N. C.
Sarma, P. L. (Student), Louisiana State Univ., Baton Rouge, La.
Stern, H. E., Fairchild Engine & Airplane Corp., Oak Ridge, Tenn.
Tucker, T. M., 148 Woodland Dr., Knoxville, Tenn.
Weinreb, B., TVA, Knoxville, Tenn.
Wintter, J. E., TVA, Chattanooga, Tenn.

5. Great Lakes

Allman, L. M., S. & C. Elec. Co., Chicago, Ill.
Andrzejewski, I. S., 2215 S. Madison, Bay City, Mich.
Arneson, G. S., 1726 Ashland Ave., St. Paul, Minn.
Atherton, E. W., I-T-E Circuit Breaker Co., Chicago, Ill.
Barney, A., Commonwealth & Southern Corp., Jackson, Mich.
Barta, G. T., Indiana Steel Products Co., Valparaiso, Ind.
Batalis, W., Carnegie Illinois Steel Corp., Gary, Ind.
Boland, R. G., Jr., Holt Elec. Co., Milwaukee, Wis.
Bradshaw, M. E., Pullman Standard Car Mfg. Co., Chicago, Ill.
Brown, W. E., Fansteel Metallurgical Corp., North Chicago, Ill.
Budish, I. I., Chicago Transit Authority, Chicago, Ill.
Carr, K. J., 520 W. Marion St., Elkhart, Ind.
Cobb, M. E., Westinghouse Elec. Corp., Chicago, Ill.
Collins, H. T., Underwriters' Labs., Chicago, Ill.
Culpepper, T. W., Michigan State College, E. Lansing, Mich.
Diamond, A. P., Eicor, Inc., Chicago, Ill.
Dumser, W. T. (re-election), Cline Elec. Mfg. Co., Chicago, Ill.
Durkin, R. J., 936 W. 76 St., Chicago, Ill.
Dvorak, G. F., Underwriters' Labs., Chicago, Ill.
Engelhardt, E. M., Geo. D. Roper Corp., Rockford, Ill.
Gardner, W. H., Sangamo Elec. Co., Springfield, Ill.
Gaughan, W. F., Public Lighting Comm., Detroit, Mich.
Gordon, H. J., Westinghouse Elec. Corp., Chicago, Ill.
Griffin, W. E., Minneapolis Honeywell Regulator, Minneapolis, Minn.
Haibeck, H. M., Carnegie-Illinois Steel, Chicago, Ill.
Hart, J. P., Central Illinois Light Co., Peoria, Ill.
Hosford, M. J., Allison Div., General Motors Corp., Indianapolis, Ind.
Hval, N. I., Montana-Dakota Utility Co., Minneapolis, Minn.
Kallas, F. A., Scovill Mfg. Co., Racine, Wis.
Kerndt, C. G., Wisconsin Pr. & Lt. Co., Madison, Wis.
Kindt, W. F., 2670 N. 40th St., Milwaukee, Wis.
King, W. B., Pontiac Senior High School, Pontiac, Mich.
Koslosky, H. E., Cutler Hammer, Milwaukee, Wis.
Luce, H. W., Public Service Co. of Northern Illinois, Chicago, Ill.
Mees, J., Jr., U. S. Naval Ordnance Plant, Indianapolis, Ind.
Mitchell, J. R., Jr., Commonwealth & Southern Corp., Jackson, Mich.
Mueller, A. G., Square D Co., Milwaukee, Wis.
Murphy, D. J., Cline Elec. Mfg. Co., Chicago, Ill.
Parfitt, R. H., General Motors Corp., Milwaukee, Wis.
Pomeroy, O. R., Univ. of Illinois, Urbana, Ill.
Roberts, W. E., 4125 S. Austin St., Milwaukee, Wis.
Scharch, G. J., No. Indiana Public Service Co., Michigan City, Ind.
Scott, E. A., Westinghouse Elec. Corp., Chicago, Ill.
Simmons, R. H., Federal Power Comm., Chicago, Ill.
Smythe, R. L. (re-election), Line Material Co., Milwaukee, Wis.
Soloff, R., Underwriters' Labs., Inc., Chicago, Ill.
Swanson, W. F., Westinghouse Elec. Corp., Chicago, Ill.
Tennessen, W. J., Commonwealth Tel. Co., Madison, Wis.
Turk, F. F., 25 N. Alfred St., Elgin, Ill.
Vandivere, E. J., 264 Marion St., Elmhurst, Ill.
Waelty, M. F., Westinghouse Elec. Corp., Chicago, Ill.
Woolsey, W. P., Eli Lilly & Co., Indianapolis, Ind.
Yost, W. W., Allison Div., General Motors Corp., Indianapolis, Ind.
Zang, H. W., Giffels & Vallet, Inc., Detroit, Mich.

6. North Central

Allen, A. V., Black Hills Power & Light Co., Rapid City, S. Dak.
Drane, G. M., Bureau of Reclamation, Kortes Dam, Wyo.
Frahm, W. J., Box 91, Oelrichs, S. Dak.
Johnson, J. M., Jr., U. S. Bureau of Reclamation, Denver, Colo.
McKernon, W. D., Sturgeon Elec. Co., Lakewood, Colo.
McQuate, P. L., Bureau of Reclamation, Casper, Wyo.
Morroni, D. J., Elec. Equipment & Engg. Co., Denver, Colo.
Peterson, W. H., Phippsburg, Colo.
Prechtel, H. R., Jr., 1270 Elizabeth St., Denver, Colo.
Thorn, O. W., Bureau of Reclamation, Grand Island, Nebr.
Veburg, J. C., I. B. M. Corp., Lincoln, Nebr.
Wray, V. B., 4070 Depew St., Denver, Colo.

7. South West

Aguirre y A., O., Industria Electrica de Mexico, S. A., Mexico, D. F., Mexico
Arnold, H. J., Jr., Univ. of Arkansas, Fayetteville, Ark.
Ayllon, A., V., Industria Electrica de Mexico, S. A., Mexico, D. F., Mexico
Barnett, G. G., U. S. Rubber Co., Houston, Tex.
Baron, J. H., Vickers Elec. Div. of Vickers Inc., St. Louis, Mo.
Beasley, L., Southwestern Public Service Co., Lubbock, Tex.
Becker, W. D., Univ. of Missouri, Columbia, Mo.
Binder, R. J., Sverdrup & Parcel, Inc., St. Louis, Mo.
Blue, F. C., Phillips Petroleum Co., Phillips, Tex.
Brown, J. K., City of Lubbock Elec. Dept., Lubbock, Tex.
Clubb, A. J., Jr., Sun Oil Co., Beaumont, Tex.
Darnell, W. L., Jr., Texas Elec. Service Co., Wichita Falls, Tex.
Davis, P., Texas Elec. Service Co., Ft. Worth, Tex.
Doolittle, H. H., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Dougherty, H. P., Jr., Union Elec. Co. of Mo., St. Louis, Mo.
Dyer, R. C., Jr., Texas Elec. Service, Ft. Worth, Tex.
Gassman, F. C., Union Elec. Co. of Mo., St. Louis, Mo.
Gerhard, G. R., M. W. Kellogg Co., El Dorado, Kans.
Griffith, J. W., Southern Methodist Univ., Dallas, Tex.
Hafner, W. J., Vickers Elec. Div. of Vickers Inc., St. Louis, Mo.
Helms, W. B., Southwestern Public Service Co., Borger, Tex.
Holeman, J. S., Public Service Co. of Okla., Tulsa, Okla.
Horton, F. W., Brown Instrument Co., Dallas, Tex.
Hudson, D. M., A. P. Green Fire Brick Co., Mexico, Mo.
Hughston, T. D., Jr., Texas Elec. Service Co., Big Spring, Tex.
Jones, G. H., Ther Herrmann Co., Kansas City, Kans.
Karr, R. P., 712 Bennington Ave., Kansas City, Mo.
Kraus, R. P., Century Elec. Co., St. Louis, Mo.
Latham, C. L., Western Union Telegraph Co., Kansas City, Mo.
McCarroll, D. B., 2506—26th St., Lubbock, Tex.
Meyers, G. W., Vickers Elec. Div., St. Louis, Mo.
Murphey, A. N., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Pillsbury, F. H., Century Elec. Co., St. Louis, Mo.
Quinn, C. R., Central Power & Light Co., Corpus Christi, Tex.
Ramsey, R. E., Otis Elevator Co., Dallas, Tex.
Rowe, H. R., Southwestern Gas & Elec. Co., DeQueen, Ark.
Scruggs, E. B., Westinghouse Elec. Corp., St. Louis, Mo.
Siler, H. N., 842 E. B'way, Cushing, Okla.
Skiles, J. J., Univ. of Missouri, Rolla, Mo.
Sunderland, W. D., Vickers Elec. Div. of Vickers Inc., St. Louis, Mo.
Weber, E. G., Southwestern Public Service Co., Amarillo, Tex.
Whipple, R. D., 2539 University Dr., Ft. Worth, Tex.
Whitmore, P. G., General Elec. Co., Dallas, Tex.
Winborn, W. W., Public Service Co. of Oklahoma, Tulsa, Okla.

8. Pacific

Amorsen, L., Pacific Gas & Elec. Co., San Francisco, Calif.
Blaylock, R. E., 220 Commercial Nat'l Bank Bldg., Little Rock, Ariz.
Brierley, E. W., CALAPCO, Phoenix, Ariz.
Burges, H. B., Salt River Valley Water Users Assoc., Phoenix, Ariz.
Corrin, J. G. (re-election), Pennsylvania Transformer Co., Los Angeles, Calif.
Cudlin, L. F., General Elec. Co., Los Angeles, Calif.
Erickson, C. A., Dept. of Water & Power, Los Angeles, Calif.
Fabrizio, A. N., 5415 N. Figueroa St., Los Angeles, Calif.
Gardner, R., Ariz. Edison Co., Inc., Phoenix, Ariz.
Ingraham, V. B., U. S. Naval Station, San Diego, Calif.
Keyfauver, B. F., Graybar Elec. Co., Inc., Phoenix, Ariz.
Knight, W. B., So. California Edison Co., Los Angeles, Calif.
Lee, G. S., Sverdrup & Parcel, San Francisco, Calif.
Maki, G. J., State of Calif., Sacramento, Calif.
Norris, D. A., Central Arizona Light & Power Co., Phoenix, Ariz.
Phillips, E. T., Univ. of California, Berkeley, Calif.
Price, F. P., Consolidated Vultee Aircraft Corp., San Diego, Calif.
Sagaser, R. L., Pacific Gas & Elec. Co., Selma, Calif.
Scolari, E., Lompoc Light & Water Dept., Lompoc, Calif.
Scott, R. C., Jr., Westinghouse Elec. Corp., San Francisco, Calif.
Smith, I. L., Columbia Steel Co., Oakland, Calif.
Travaillie, L. M., General Elec. Supply Corp., San Francisco, Calif.
Tweedy, R. E., Westinghouse Elec. Supply Co., Phoenix, Ariz.
Vetromile, J. P., Pacific Gas & Elec. Co., San Francisco, Calif.

9. North West

Cole, C. D., Corps of Engineers, Walla Walla, Wash.
Crane, W. F., U. S. Army Eng., Walla Walla, Wash.
Davis, D. L., Boeing Airplane Co., Seattle, Wash.
Downing, D. M., R.F.D. #1, Box 38, Lyons, Oreg.
Edwins, D. L. H., Boeing Airplane Co., Seattle, Wash.
Malone, W. W., 6915 N. E. Union Ave., Portland, Oreg.
Richmond, A. E., P. O. Box 441, Portland, Oreg.
Sever, R. E., Bonneville Power Administration, Portland, Oreg.
Shelley, R. E., Washington Water Power Co., Spokane, Wash.
Theiss, C. M., Boeing Airplane Co., Seattle, Wash.

10. Canada

Allworth, J. C., Dept. of National Defense, Ottawa, Ontario, Canada
Anderson, D. E., Westinghouse Co., Ltd., Hamilton, Ontario, Canada
Armstrong, H. W. D., Univ. of British Columbia, Vancouver, British Columbia, Canada
Doughty, K. W., Canadian General Elec. Co., Ltd., Toronto, Ontario, Canada
Gerin-Lajoie, P., Canadian General Elec. Co., Toronto, Ontario, Canada
Hughes, S. D., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Kapsa, J. .. Canadian General Elec. Co. Ltd., Toronto, Ontario, Canada
Langdon-Davies, W. B., B. C. Elec. Co. Ltd., Abbotsford, British Columbia, Canada
Lindgaard, H. C., 509 Richards St., Vancouver, British Columbia, Canada
Lovett, J., Northern Elec. Co., Ltd., Montreal, Quebec, Canada
Maude, K. S., Elec. Power Equipment Ltd., North Vancouver, British Columbia, Canada
McCorquodale, W. A. H., Northern Elec. Co., Montreal, Quebec, Canada
McLeod, W. C., Canadian Westinghouse Co., Ltd., Hamilton, Ontario, Canada
McPherson, W. H., The Hydro-Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Ogston, W. G., Canadian Comstock Co. Ltd., St. Catharines, Ontario, Canada
Sherman, J. A., Canadian Westinghouse Co., Hamilton, Ontario, Canada
Simpson, W. R., Hydro Elec. Power Commission of Ontario, Hamilton, Ontario, Canada
Sinclair, A. M., Hydro-Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Troalen, P., Shawinigan Water & Power Co., Trois Rivieres, Quebec, Canada
Tyynela, R., Canadian General Elec. Co., Toronto, Ontario, Canada
Woods, W. S., Bell Tel. Co., Toronto, Ontario, Canada

**Elsewhere**

Bhatia, D. J., M/s. Amreli Electricity Co. Ltd., Amreli, Bombay, India
Bhatt, R. J., Caylon Technical College, Colombo, Ceylon
Bhatty, M. H., Military Engrs. Service, Govt. of Pakistan, Quetta Cantt, West Pakistan
Gallego, M., Jr., Philippine Legation, London, England
Gandhi, G. M., Tata Hydro Companies, Bombay, India
Ghose, A. K., Calcutta Elec. Supply Corp. Ltd., Calcutta, India
Gibbs, R. E., Acetone Illuminating & Welding Co., Christchurch, New Zealand
Kennedy, J. A., Metropolitan Vickers Electrical Co., Manchester, England
Khalil, K. A., N.W.F.P. Pakistan, Peshawar, India
Krishnamurti, K. C., Central Electricity Comm., Govt. of India, Simla, India
Love, A. R., New Zealand Railways, Wellington, New Zealand
Wheeler, R. K., General Elec. Co. Ltd., Witton, Birmingham, England

Total to grade of Associate

United States, Canada, and Mexico, 301
Elsewhere, 12

# OF CURRENT INTEREST

## First Pan American Engineering Congress Held in Brazil; UPADI Charter Approved

The formal opening of the First Pan American Engineering Congress took place on the evening of July 15, 1949, at the Municipal Theatre in Rio de Janeiro, Brazil. Several chiefs of delegations, including the Chairman of the United States delegation, S. S. Steinberg, Dean of Engineering at the University of Maryland, delivered addresses. The scheduled sessions of the Congress and its Commissions commenced the next day, lasting until July 20.

The First Pan American Engineering Congress, officially authorized and sponsored by the Government of Brazil, was attended by 800 engineers, officials, and guests, representing nearly all the countries of the Western Hemisphere. Of the registered engineers, 540 were Brazilians. The next three largest registrations were 74 from Argentina, 40 from the United States, and 36 from Uruguay, all exclusive of their families. Approximately 350 papers were represented of which more than 100 were from United States engineers. The large number of papers from the United States is due largely to the work in developing the interest of North American engineers done by L. J. Hughlett of the Committee for United States Participation in the Congress. The official United States delegation consisted of 17 members of the five constituent societies of Engineers Joint Council, including W. W. Parker (M '47).

The program of the Congress dealt with all major branches of engineering. The subjects were classified under the following headings: Transportation and Communications; Construction; Power; Urban and Rural Engineering; Sanitary Engineering; Industrial Engineering; Mining Engineering and Geology; Teaching of Engineering; as well as Miscellaneous. The presiding officer was engineer F. Saturnino de Brito Filho. Official languages of the Congress were English, French, Portuguese, and Spanish. Translations were made at the meetings as needed and requested by the delegates. Of the 350 papers presented, more than a third were in English, somewhat less than a third in Portuguese, a smaller number in Spanish, and only a few in French.

In the interim between Congress sessions, meetings of the Committee on the Constitution for the proposed Pan American Union of Engineering Societies (UPADI) were held, and at the final session of this committee the Constitution for UPADI was unanimously approved. It was decided that when the engineering societies of 15 nations have accepted the document, then UPADI would be considered formed.

Also, prior to the meeting of the Congress, preliminary meetings for the organization of UPADI were held in Sao Paulo, Brazil. They took place from July 9 to July 14.

The United States delegation made the unanimous recommendation to the Engineers Joint Council that it urge its constituent societies to study the UPADI Constitution and to take action to join.

### Future Meetings of Other Societies

**American Association for the Advancement of Science.** 116th Annual Meeting. December 26–31, 1949, Hotels Statler, Governor Clinton, New Yorker, McAlpin, and Martinique, New York, N. Y.

**American Institute of Chemical Engineers.** National Meeting. December 4–7, 1949, William Penn Hotel, Pittsburgh, Pa.

**American Meteorological Society.** 30th Anniversary Meeting. January 3–6, 1950, St. Louis, Mo.

**American Petroleum Institute.** 29th Annual Meeting. November 7–10, 1949, Stevens Hotel and Palmer House, Chicago, Ill.

**American Society of Mechanical Engineers.** Annual Meeting. November 27–December 2, 1949, Hotel Statler, New York, N. Y.

**Exposition of Chemical Industries.** November 28–December 3, 1949, Grand Central Palace, New York, N. Y.

**Institute of Radio Engineers.** Second Southwestern Conference. December 9–10, 1949, Baker Hotel, Dallas, Tex.

**National Council of State Boards of Engineering Examiners.** 28th Annual Meeting. November 10–12, 1949, Sheraton Plaza Hotel, Daytona Beach, Fla.

**National Electrical Contractors Association.** Annual Convention. November 7–10, 1949, Rice Hotel, Houston, Tex.

**National Electrical Manufacturers Association.** November 14–18, 1949, Chalfonte-Haddon Hall, Atlantic City, N. J.

**National Research Council.** Conference on Electrical Insulation of the Division of Engineering and Industrial Research. November 7–9, 1949, Pocono Manor Inn, Pocono Manor, Pa.

**Pacific Industrial Conferences–Pacific Chemical Exposition.** November 1–5, 1949, San Francisco Civic Auditorium, San Francisco, Calif.

**Petroleum Electric Power Association.** Annual Conference. November 17–18, 1949, Hotel Beaumont, Beaumont, Tex.

**Refrigeration Equipment Manufacturers Association.** 6th All-Industry Refrigeration and Air Conditioning Exposition. November 14–18, 1949, Atlantic City Auditorium, Atlantic City, N. J.

**Society of Automotive Engineers.** January 9–13, 1950, Hotel Book-Cadillac, Detroit, Mich.

## Rapid Selector, Electronic "Brain," Scans 60,000 Subjects Per Minute

A new electronic "brain," developed jointly by the United States Department of Agriculture and Department of Commerce, stores vast amounts of scientific information in its system, automatically "pores" over it, selects what is sought after by its operator, and then hands him copies of what he wants. Known as the Rapid Selector, the device was developed from principles originated before the war by Dr. Vannevar Bush, then at the Massachusetts Institute of Technology.

The Office of Technical Services of the United States Department of Commerce, under the direction of John C. Green, appropriated more than $75,000 for the perfection of the machine which was developed by Engineering Research Associates of Minneapolis, Minn., under the supervision of Ralph R. Shaw, Librarian of the Department of Agriculture. The prototype machine is now being tested for performance at the Agriculture Department library under Mr. Shaw's direction and persons wishing to inspect it may arrange with him to do so.

The Rapid Selector makes use of standard 35-millimeter motion-picture films on each reel of which can be stored the contents of almost 500,000 conventional library cards. When the information is microfilmed, a predetermined code pattern, consisting of black and white squares, is simultaneously printed on the film indicating the subject.

The operator of the machine, wishing to obtain everything the selector possesses on a particular subject, places a master key card in the mechanism. The selector's photoelectric eyes then scan the film at a rate of more than 60,000 subjects a minute, automatically select the desired frames, and copy them on a separate film through the use of high-speed photoflash techniques.

As an example of how the new machine might eliminate the burdensome time factor in bibliographical research, an estimate has been made indicating that it would take the Rapid Selector only about 15 minutes to review all the entries that have appeared in the last 30 years in "Chemical Abstracts." This, of course, presupposes that the abstracts have first been transferred to microfilm and properly coded with light patterns for use in the machine.

The selector, which can potentially be coded for ten million different subjects, uses a principle similar to photoelectric cells in door-opening devices. In such devices, when a person's body cuts off the beam of light, the photoelectric relay opens the door. In a like manner, the Rapid Selector scans the patterns of light and dark accompanying each film frame "looking" for a particular pattern to match the master key inserted in the machine. When the two coincide, a flashlamp is fired photographing the frame then passing through the scanning area.

This flash results in a copy of the item of information desired by the operator. When a complete reel has passed through the machine, the researcher has a complete and accurate bibliography of the subject in a minimum of time. A repeating flashlamp similar to those used by photographers is used because of its brilliant beam which lasts only two millionths of a second, thereby stopping the swiftest motion for the camera.

The basic features of the machine are unpatented and in the public domain, and a report describing the Rapid Selector in detail and accompanied by illustrations (PB 97535, $2.50 per copy) is available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C. Orders should be accompanied by check or money order payable to the Treasurer of the United States.

## Engineering Societies Library Reduces Rates for Loan of Books

Members of the AIEE can now borrow books from the Engineering Societies Library for only 50 cents a week for each volume borrowed. Formerly the charge was 60 cents. Henceforward, a 2-week loan on one book, or a 1-week loan on two books, can be paid by sending one dollar to the library when the material is returned. It is hoped that many members will find it convenient to pay for loans this way as it helps to keep loan charges low by eliminating billing costs.

Despite all efforts to reduce loan costs, a charge is necessary. The amount of a member's dues allotted to the library is not enough to cover the average cost of the loan of one book. The charge covers only handling costs, including wrapping, postage, and insurance.

Borrowing is kept as simple as possible. No particular form is required. If not visiting the library in person, the member should make his request in writing, stating his membership affiliation, and being as explicit as possible with regard to the material desired. Inasmuch as the library's material is valuable and much of it in frequent demand, the Library Board has established the following rules governing the loan of books:

1. Books, including bound serial publications, may be borrowed by any member of a Founder Society, if in good standing and residing in the continental United States or Canada. (Applicants are asked to name their society.)

2. A charge of 50 cents a week or fraction of a week will be made for each volume borrowed.

3. The maximum length of time for any loan is two weeks, not counting time in transit.

4. Members may have as many as three volumes on loan at one time.

5. Return postage and insurance must be paid by the borrower. Members in Canada also pay forwarding postage.

6. Rare books and reference books are lent only after approval by the Library Board.

Requests should be addressed to the Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

## Philco Microwave Relay System Replaces R R Telephone Lines

The Philco Corporation will provide the Chicago, Rock Island and Pacific Railroad with new microwave relay equipment which will be used in the first railroad-operated microwave communications system in the United States.

This new equipment is so designed that a complete 2-way repeater station can be mounted on a simple supporting structure. The use of this communications repeater equipment will enable the Rock Island to replace telephone lines between Goodland and Norton, Kans., a distance of 110 miles. This route was chosen for the first installation because of the high mortality of telephone lines during the winter's severe ice, sleet, and snow storms. In addition to the terminal stations at Goodland and Norton, automatic repeater stations will be installed to provide communications for intermediate points.

The equipment will be used to provide five voice channels, one control, and one telemetering channel for the Rock Island. The microwave relay system can be expanded to handle up to 32 voice channels, plus a number of telegraph, teletype, and signaling circuits.

The heart of the system, the microwave communications relay, represents the first successful application of the feed-back principle in the microwave field. This relay equipment is automatic, compact, and inexpensive and represents a new departure in microwave communications techniques.

Microwave communications relays, which provide the only practical way of replacing telephone lines, have the advantages of highly directive beamed radiation and great power gain. Microwave relay systems have previously been used in the United States and Europe to relay television programs, telephone calls, and telegrams, but the Rock Island installation represents the first railroad application of this postwar development.

## Annual Summer Lightning Study Conducted by GE Scientists

Lightning has struck the antenna atop the Empire State Building in New York, N. Y., 24 times during storms this summer, according to Julius H. Hagenguth (M '44), head of the General Electric Company engineers conducting lightning research atop the building. This is the ninth year that the company's "lightning scientists" have conducted these Empire State Building lightning studies.

This summer, complete photographic records and electrical measurements were obtained on all lightning strokes hitting the National Broadcasting Company's frequency-modulation and television antenna on the building. By scientific analysis of records obtained when these bolts hit, new information was gained which will contribute further to the control of the effects of lightning. Such information also will be useful for application in the laboratory where artificially-produced lightning is used to test electric apparatus.

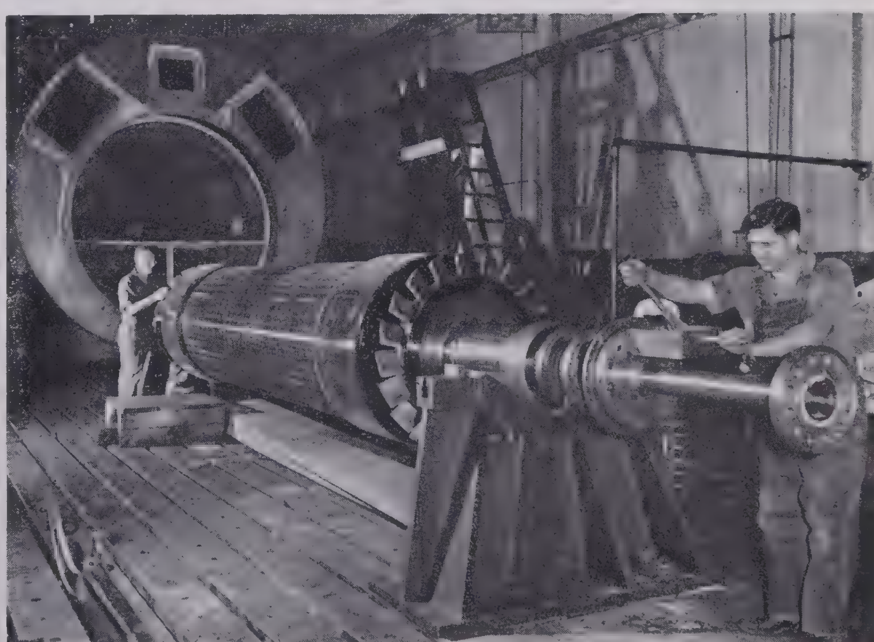
With strategically located photographic and recording devices, the engineers determined the exact currents in each lightning bolt, the length of time each stroke lasted, the intensity of the light produced by the lightning, and the physical shape or path of the stroke.

A heavy copper cable extending through the interior of the antenna atop the building carried the lightning stroke current to oscillographs in the "attic" of the building, where the current amplitude and the wave shape were recorded. At night, photographs of each stroke were taken simultaneously from two different locations at right angles to the building. This permitted the engineers to obtain a 3-dimensional view of the stroke and to determine its exact length.

An "electronic brain," an automatic corona device mounted on the top railing of the building, acted as a storm "watchman," turning on all oscillographic recording equipment as storms approached the city or as storm fields formed around the building. One thus did not need to be on hand immediately to gather data. The device can be made so sensitive that a heavy fog may start the recording machines.

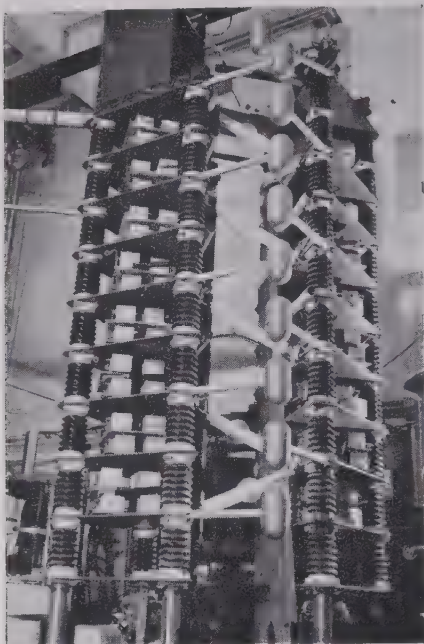
Two manually-operated cameras were set up atop a building at 521 Fifth Avenue—one a high-speed camera and the other a slow-speed multiple-aperture camera. They take up to 20 photographs with a single loading of film. A third camera, called the "oblique camera," was located atop the

## Westinghouse 81,000-Kw Generator



**This 60-ton rotor being finished at the East Pittsburgh (Pa.) works of the Westinghouse Electric Corporation forms part of an 81,000-kw generator soon to be installed at the Phillips' Power Station of the Duquesne Light Company, Pittsburgh, Pa. Forty inches in diameter and more than 25 feet long, this rotor will revolve 3,600 times a minute**

# Eight-Stage Capacitor



**Shown is an 8-stage capacitor, a rectifier multiplier which supplies 600,000 volts d-c starting potential to the electron gun of the University of Michigan's "Racetrack" synchrotron. Plastic film is the dielectric used in the capacitors. Trademarked "Plasticons," the capacitors are manufactured by the Condenser Products Company, Chicago, Ill. The "Racetrack" accelerates electrons to 300,000,000 electron volts**

Hotel New Yorker, west of the Empire State Building. A slow-speed camera taking one picture every minute, it photographed each stroke at a right angle to the exposure field of the two cameras on Fifth Avenue. The motor which runs this camera could be started by a remote-control telephone device from the Fifth Avenue location.

To determine the degree of cloudiness caused by rain, fog, smoke, or other foreign material, a light of known intensity was reflected by a parabolic mirror to a photoelectric cell at the Fifth Avenue camera location, the photoelectric cell measuring the brightness of the light. This record was used as a comparison, so that the engineer gathering the lightning data could evaluate more accurately the intensity of the lightning stroke.

Although the equipment was scattered over several city blocks, only one man was needed to tend the machines and gather the information. This was done by Robert H. Ochs, an engineer in General Electric's High-Voltage Engineering Laboratory.

**Midwes Quality Control Conference.** The fourth Midwest Quality Control Conference is to be held at St. Louis, Mo., at the Jefferson Hotel on Thursday and Friday, November 10 and 11, 1949. Sponsored by the American Society for Quality Control, it will consist of a series of clinical sessions, two luncheon meetings, and a training program. This 2-day conference has been planned to acquaint representatives of industry with some of the methods of modern quality control, its theme being "greater quality—better quality—lower cost." Two series of six clinical sessions each, to be held concurrently, have been arranged. An introductory series will be held for those who have no previous acquaintance with quality control, and a more advanced series will present a number of special technical methods and their applications, slanted to those who have had some previous experience in quality control. Industries presenting their experience include shoes, textiles, toiletries, foods, mechanical, service, and others. The 2-day basic training program in quality control by statistical methods will be suitable for personnel of all supervisory levels who have had no previous acquaintance with quality control techniques. It will present the basic principles and methods involved, the preparation of control charts, and their use in helping to maintain quality. Hotel reservations should be made directly with the Hotel Jefferson, 12th and Locust Streets, St. Louis, Mo. In making reservations, refer to the conference so that room assignments may be made from those reserved for conference guests.

## AAAS to Hold 116th Meeting, 2,500 Papers Are Planned

The American Association for the Advancement of Science, the largest scientific organization in the world representing all branches of science, will hold its 116th meeting in New York, N. Y., from December 26 to 31, 1949. All of the association's 17 sections and subsections, plus 56 of its 211 affiliated and associated societies, will present programs There will be approximately 2,500 scientific papers listed in the 375-page general program to be published by December 1. The headquarters hotels will be the Statler, New Yorker, McAplin, Governor Clinton, and the Martinique.

Organized in Philadelphia in 1848, the association has held five of its annual meetings in New York City. Dr. Edmund W. Sinnott of Yale University is Retiring President of the Association and Dr. Elvin C. Stakman of the University of Minnesota is President. Dr. Howard A. Meyerhoff is Administrative Secretary with headquarters at 1515 Massachusetts Avenue, N. W., Washington 5, D. C.

With an initial membership 101 years ago of 461, individual memberships in the association now exceed 45,000. Members of its associated and affiliated societies number well over a million, with the Council of the AAAS, comprising about 260 prominent scientists.

## RDB's Authority Over Military Increased by New Directive

A new directive, extending the authority and responsibility of the Research and Development Board in compliance with the terms of the recent amendments to the National Security Act, has been signed by Secretary of Defense Louis Johnson.

The Research and Development Board now has, in addition to the responsibility for formulating a complete integrated program of research and development for military purposes, the authority to determine whether its program is being carried out by the three military departments.

This means that the board may, as it deems necessary, direct changes in the programs of the services, including the initiation of new projects, the increase of effort in certain areas, and the decrease or curtailment of effort in other areas. Hitherto, the role of the Research and Development Board has been largely advisory and co-ordinative.

## OTS to Continue Its Operations, Halves Price of Bibliography

The Office of Technical Services (OTS) of the United States Department of Commerce is continuing its basic technical-information services for industry during the coming 12-month period. The OTS, which was granted a slight increase in its appropriation for the current fiscal year, will emphasize services particularly useful to smaller firms.

The subscription price of the *Bibliography of TECHNICAL REPORTS*, the OTS monthly journal of technical abstracts, has been halved and is now available at $5 per year. While the size of each issue will be reduced, emphasis will be placed on selecting the most promising reports, and providing descriptive information with each regular entry.

A *Newsletter* is also now being published monthly, and is available at 50 cents per year. It is a bulletin highlighting business opportunities arising from federal research. Subscribers to the *Bibliography* receive the *Newsletter* without additional cost. Free sample copies of the *Newsletter* are available from OTS on request.

During the coming fiscal year OTS hopes to strengthen its technical-inquiry program. The Office is particularly interested in co-operative arrangements with state, regional, and local development agencies, as well as trade associations and similar groups, and invites them to write for further particulars.

**AEC Names Cook Manager at Oak Ridge.** Richard W. Cook, Acting Manager of the Atomic Energy Commission's Office of Oak Ridge Operations, has been named Manager. Mr. Cook succeeds J. C. Franklin, former airline official, who resigned the post at Oak Ridge last June after nearly two years service. As Manager, Mr. Cook will administer all contracts for the AEC at Oak Ridge covering operation of the big uranium 235 production plants, the Oak Ridge National Laboratory, the community of Oak Ridge, and other related activities within the area. Also under his administration is the contract for operation of the Commission's Dayton, Ohio, Area, including a laboratory at Miamisburg, Ohio, and a second newly constructed facility at Marion, Ohio. Mr. Cook is a veteran of more than five year's experience with the atomic energy project, having been assigned to the Manhattan Engineer District at Oak Ridge in July 1944. Graduated from

Michigan State College in 1933 with a civil engineering degree, he served with the Army Quartermaster Corps and Corps of Engineer prior to going to Oak Ridge.

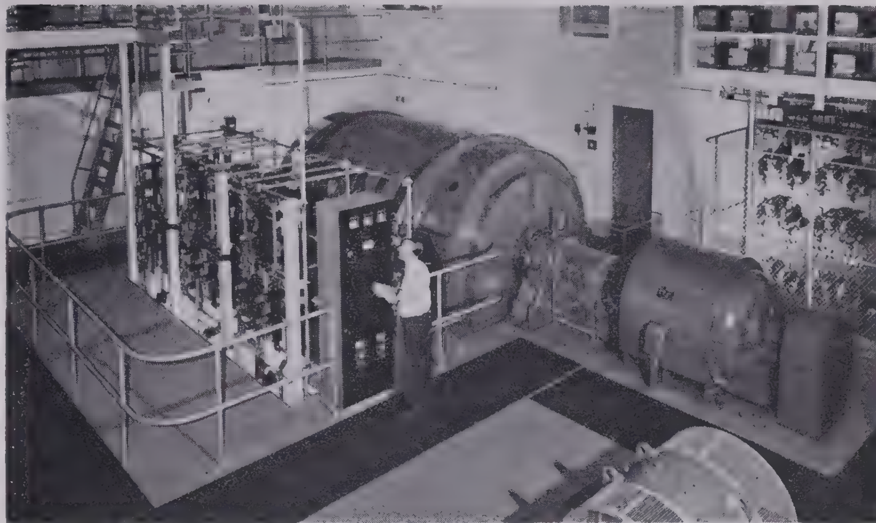
**Aldridge Gets Engineering Award.** Walter Hull Aldridge was elected to receive the John Fritz Medal for 1949. Mr. Aldridge has been president of the Texas Gulf Sulphur Company for more than 30 years, is a trustee of Columbia University, and holder of the honorary degree doctor of science. He is cited for the present award as "engineer of mines and statesman of industry who by his rare technical and administrative skills has importantly augmented the mineral production of our country and Canada." The John Fritz Medal and certificate are presented not more often than once each year "for scientific or industrial achievement" in any field of pure or applied science. It was established in 1902 as a memorial to the engineer and steel maker whose name it bears, and is jointly sponsored by the Founder Societies of civil, mining, mechanical, and electrical engineers.

**Warner Receives Aviation Award.** Edward Pearson Warner has been elected to receive the Daniel Guggenheim medal and certificate for 1950 for "pioneering in research and a continuous record of contributions to the art and science of aeronautics." Dr. Warner is president of the Interim Council of the Provisional International Civil Aviation Organization and has held many government posts in the aeronautical field. The Daniel Guggenheim Medal was created for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. Provision for the medal was made in 1928 by the gift of a fund from the Daniel Guggenheim Fund for the Promotion of Aeronautics. Some previous recipients of this medal are Orville Wright, Boeing, Douglas, Martin, General Doolittle, Bell, and Grumman.

**ASEE Section to Meet in Rochester.** The Fourth Annual Meeting of the Upper New York Section of the American Society for Engineering Education will be held in Rochester, N. Y., November 18–19, 1949. Host will be the University of Rochester with the Eastman Kodak Company as sponsors. According to the preliminary program, registration will take place Friday morning, November 18. In the afternoon, there will be an inspection trip to the Eastman Kodak Company followed by dinner and an evening program at Kodak Park. Saturday morning, the general session and business meeting will be held. Subsequently, there will be a visit to the University of Rochesters' cyclotron laboratory and an afternoon technical conference.

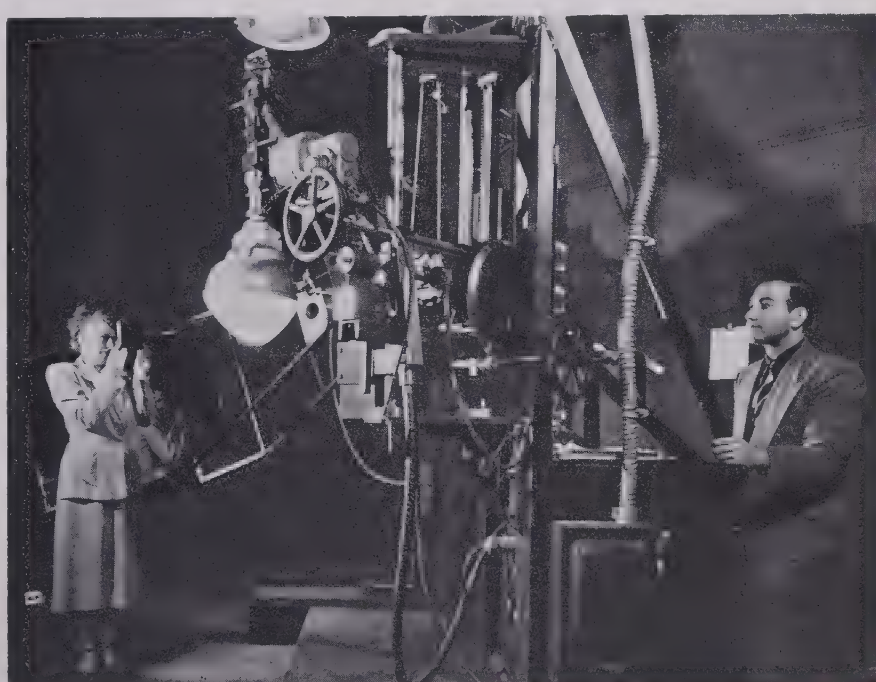
**ASEE Officers Elected.** Thorndike Saville, Dean of Engineering at New York (N. Y.) University, has been elected President of The American Society for Engineering Education for the year 1949–50. The newly

## Short-Circuit Laboratory Generator



**The 500,000-kva generator and 800-horsepower 2,300-volt induction motor shown above are being used in the Line Material Company's new Short-Circuit Laboratory at South Milwaukee, Wis., to test electric circuit-interrupting devices. The generator, a 60-cycle 3-phase unit, delivers voltages ranging from 2,200 to 15,000, and, using a transformer, 60,000 volts can be obtained; it is driven by the induction motor at a speed of 3,600 rpm. Current from the generator is routed through bus and switching equipment to the unit being tested in an explosionproof cell. Nondestructive tests of apparatus are carried on in an open test area**

## Light Distribution Measurement



**In the General Electric Company's recently completed Illuminating Laboratory at Lynn, Mass., an engineering assistant inspects a luminaire through filter glass while a test engineer adjusts meters and angular scales prior to making a light-distribution measurement. Test is made in a specially designed distribution photometer which records light intensities at various angles**

## Cleveland Gets New Transformer

**A new General Electric power transformer, installed at a Cleveland (Ohio) Electric Illuminating Company plant, is part of the utility's program to raise the plant's capacity to 400,000 kw. When self-cooled, the transformer is rated at 15,000 kw, and when forced-air-cooled, 25,000 kw**

elected Vice-Presidents of the society include B. J. Robertson, Professor of Mechanical Engineering at the University of Minnesota, Minneapolis, and H. H. Armsby, Specialist in Engineering Education, United States Office of Education. F. E. Terman, Dean of Engineering at Stanford University, Calif., was named Vice-President in charge of the society's Engineering College Administrative Council; F. M. Dawson, Dean of Engineering at the State University of Iowa, Iowa City, continues as Vice-President in charge of the society's Engineering College Research Council. James S. Thompson, formerly Vice-Chairman of the Board of Directors of McGraw-Hill Book Company, New York, N. Y., was re-elected Treasurer.

**British Photo Society Honors Kodak Scientist.** Dr. Loyd A. Jones, head of the Physics Department at Kodak Research Laboratories, Rochester, N. Y., has been elected an honorary fellow of Great Britain's Royal Photographic Society. Election is considered a signal honor. The Kodak research scientist was cited for his "distinguished contributions . . . to photography and its applications, particularly in the field of sensitometry." It is the third recognition of Dr. Jones by the society this year. In February he was awarded the society's 1948 Progress Medal. In May he lectured before its members in London and received the Hurter and Driffield medal. Dr. Jones joined Eastman Kodak Company in 1912 as one of the first staff members of the company's research laboratories. He has done work in the fields of optics, motion picture engineering, photometry, and colorimetry.

**ASME Names Cunningham President.** James D. Cunningham, president of Republic Flow Meters Company, Chicago, Ill., is the 1950 nominee for President of The American Society of Mechanical Engineers (ASME). He heads a slate of new officers, including four regional vice-presidents and two directors-at-large. The new officers will begin their terms at the end of the ASME annual meeting in New York, N. Y., next December. Mr. Cunningham will succeed James M. Todd, consulting engineer of New Orleans, La. Regional vice-presidents nominated are: Frank M. Gunby, (renomination) of Charles T. Main, Inc., Boston, Mass.; Professor John C. Reed, head of mechanical engineering department, Bucknell University, Lewisburg, Pa.; Albert C. Pasini, assistant superintendent, production department, Detroit (Mich.) Edison Company; Samuel H. Graf, director, engineering experimental station, Oregon State College, Corvallis, Oreg. Nominated as directors-at-large are: Thomas E. Purcell, general superintendent, power stations, Duquesne Light Co., Pittsburgh, Pa.; and Benjamin P. Graves, director of design, Brown and Sharpe Manufacturing Company, Providence, R. I.

**Electrical Manufacturing Makes Awards.** Five awards for outstanding achievement in the design of new electrically operated products are announced by *Electrical Manufacturing* as the result of the Eleventh Annual Product Design Competition sponsored by the Gage Publishing Company, New York, N. Y., publishers of *Electrical Manufacturing.* Awards have been made to: the American Optical Company, Southbridge, Mass., for an ophthalmic lens blocker; to the Byron Jackson Company, Los Angeles, Calif., for a high-pressure stuffingboxless pump; to the General Electric Company, Schenectady, N. Y., for a 2-magnet industrial brake; to Hermon Hosmer Scott, Inc., Cambridge, Mass., for a miniature sound level meter; and to the Wheelco Instruments Company, Chicago, Ill., for a deflection-type temperature recorder. Stories of the award-winning product developments appear in the October issue of *Electrical Manufacturing.*

# LETTERS TO THE EDITOR

**INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.**

## Symbolic Nomenclature

*To the Editor:*

I have read with great interest the article, "Symbolic Nomenclature for Sinusoids," by Professor LePage (*EE, Jul '49, pp 561–5*). It seems to me that the difficulty involved in the complex number versus vector controversy is due mostly to the fact that we are not rigorous enough in our thoughts and language when dealing with both of these entities. Furthermore, since both a complex number and a vector with *two real* components have the same model or concrete interpretation (the familiar diagram) we tend to confuse two entities which conceptually are totally different. Finally, it should be noted that both complex numbers and the vectors of physics are distinct, special examples of what in mathematics is called a vector space.[1]

I cannot quite agree with Professor LePage when he maintains that the term vector in connection with sinusoidal quantities "is correctly employed," whereas in connection with impedances we really deal with "psuedovectors." Actually, of course, in neither of these two cases are we dealing with vectors. We recall the fact that the familiar arrow is just a model for the mathematical concepts involved. The danger in models is illustrated by the fact that even though the complex number and the 2-dimensional real vector have the same representation they are, however, distinct entities. We note the fact that a complex number is simply an ordered *pair* of *real* numbers, where the familiar $j=(0, 1)$. Complex numbers combine with each other according to three fundamental rules: addition, multiplication by a scalar, and complex number multiplication. Thus, if we take the complex numbers $V=(v_1, v_2)$ and $I=(i_1, i_2)$ (which in electrical engineering are written $v_1+jv_2$

and $i_1+ji_2$) then $V+I=(v_1+i_1,\ v_2+i_2)$ and $IV=(i_1v_1-i_2v_2,\ i_1v_2+i_2v_1)$. On the other hand, a vector is a set of ordered numbers, *real* or *complex*. The rules of addition and multiplication by a scalar yield results which are formally indistinguishable from those of complex numbers. Dot multiplication, however, is a new operation: given the vectors $\mathbf{A}=\{a_1,\ a_2\}$ and $\mathbf{B}=\{b_1,\ b_2\}$, where the components may be complex, the dot product is given[2] as $\mathbf{A}\cdot\mathbf{B}=a_1\bar{b}_1+a_2\bar{b}_2$, where the bars indicate that the conjugate is being used. We shall see in the following that the identification of complex numbers with 2-dimensional real vectors is not as profitable as identification with the 1-dimensional complex vectors which, incidentally, have no concrete interpretation.

We now turn to the first sentence of the preceding paragraph. Consider a series *RLC* circuit where the applied voltage and the current flowing are $e(t)=E\sin(\omega t+\psi)$ and $i(t)=I\sin(\omega t+\phi)$ and $E$ and $I$ are reals. The voltage equation of the circuit yields the familiar expression

$$\mathrm{Im}[Ee^{j\psi}]=\mathrm{Im}\left\{\left[R+j\left(\omega L-\frac{1}{\omega C}\right)\right]Ie^{j\phi}\right\},$$

where Im stands for "imaginary part of." In the derivation of the foregoing expression nothing enters except the relation $e^{j\delta}=\cos\delta-j\sin\delta$, which is a complex number relationship. Furthermore, the quantities $Ee^{j\psi}$ and $Ie^{j\phi}$, as well as $R-j\left(wL-\frac{1}{wC}\right)$ are complex numbers. Therefore, when we draw arrows for the first two quantities and call them "vectors" we should do the same with the third, and not call the third quantity a "pseudo-vector." It is, of course, obvious that the first two complex numbers have a different history from the third—this fact, however, does not mean that the first two quantities should rate a new name. If we distinguish the first two by the term "sinor," say, and the third by the term "vector" then we shall be speaking of "dividing a sinor by a vector" or "multiplying a vector by a sinor," we shall be using different names for exactly the same entities with resulting confusion and awkwardness.

We now turn to develop the idea of the last sentence of the second paragraph. We have seen that the identification of a complex number with a vector may be done in any one of the following two cases:

Case 1: 2-dimensional real vector
Case 2: 1-dimensional complex vector

*Case 1.* Consider the *vectors* $\mathbf{V}=\{v_1,\ v_2\}$ and $\mathbf{I}=\{i_1,\ i_2\}$. The dot product $\mathbf{I}\cdot\mathbf{V}=i_1v_1+i_2v_2$, that is, the average power. If we want to assign meaning to the cross product in this case we must consider the **V** and **I** vectors as 3-dimensional real vectors with the third component equal to zero. With this change the cross product yields a vector, perpendicular to the original vectors **V** and **I,** whose magnitude equals the reactive power, except possibly for sign.

*Case 2.* Consider the two 1-dimensional complex vectors $\mathbf{V}=\{v_1+jv_2\}$ and $\mathbf{I}=\{i_1+ji_2\}$, where $j=\sqrt{-1}$ (the $j$-notation is used only to avoid confusion). The dot product $\mathbf{I}\cdot\mathbf{V}=(i_1+ji_2)(v_1-jv_2)=i_1v_1+i_2v_2+j(i_2v_1-i_1v_2)$, that is, what is commonly called vector power. The cross product in this case is zero and hence has no meaning.

*Summary.* First, the "vector diagram" of electrical engineering is indistinguishable, strictly speaking, from what is known as the Argand diagram. They are, however, the concrete interpretation of two mathematical entities which are conceptually entirely distinct. Second, if we insist on calling the complex quantities we are dealing with "vectors" then the most profitable (but how much profit!) identification is with the 1-dimensional complex vector. In this case the dot product has meaning, but it does so only if the vectors involved are the current and voltage vectors and *in that order* (note that dot multiplication is not commutative when the components are complex, for $\mathbf{A}\cdot\mathbf{B}=\overline{\mathbf{B}\cdot\mathbf{A}}$). Finally, if $V$ and $I$ are complex numbers and **V** and **I** are 1-dimensional complex vectors we have $V\bar{I}=\mathbf{V}\cdot\bar{\mathbf{I}}$, where the left member indicates complex number multiplication. Hence, complex numbers and vectors actually have a greater degree of similarity than many of us suppose.

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1. Moderne Algebra (book), **B. L. Van Der Waerden.** Frederick Ungar Publishing Company, New York, N. Y., 1943. Pages 48–9.

2. Finite Dimensional Vector Spaces (book), **P. R. Halmost.** Princeton University Press, Princeton, N. J., 1948. Pages 86–91.



ISAAY STEMPNITZKY (A '47)

(Massachusetts Institute of Technology, Cambridge, and Brandeis University, Waltham, Mass.)


*To the Editor:*

Professor LePage has succeeded in making mountains out of sinusoidal molehills. He goes through a terrific struggle to distinguish between complex numbers and space vectors.

First, I would object to the term "vector sum" as applied to complex numbers. The fact that complex numbers represented on an Argand diagram (that is, complex plane) add visually like vectors represented in a real plane offers no excuse for confusing the two, for purposes of addition or for any other purpose. Complex numbers do not "add like vectors." They add like complex numbers.

*Z* is not a "pseudo-vector"—it is a quite self-respecting complex number in a complex plane. The impedance triangle of Figure 5 of the article does not represent vectors or sinusoids. The type of line used in an impedance triangle is related to the sinusoid not at all! It is not an "operator" until we make it one by stating that for *complex* representation

$I=E/Z$

or

$E=IZ$

Further, little is gained by deriving most "useful properties of these lines without recourse to the mathematics of complex numbers." Why make an easy job difficult? For the purposes of this article, it seems that the concept of the operator $j$ is of primary importance and far from being "largely incidental."

For his study of transients, Guillemin treats homogeneous algebraic equations and uses some relations between matrices and $n$-dimensional vectors. This reference seems irrelevant to the discussion of the article in question.

The use of $\bar{E}$ as a "complex vector" and the presence of equations 15 through 18 tend to confuse the issues.

It might have been helpful to have mentioned the pitfalls that lurk in an exponential representation of a sine wave, particularly in multiplication.

If we must use a separate word, I much prefer "phasor" to "sinor" or even a possible "cosinor." And it seems much neater to use Im( ) or Re( ) rather than ≙ to obtain the real instantaneous form.

A misleading error in symbolic nomenclature can be noted in the footnote of a recent text.[2]

REFERENCES


1. Communication Networks (book), **E. A. Guillemin.** John Wiley and Sons, Inc., New York, N. Y., 1931. Volume 1, pages 248–84.

2. Elements of Electromagnetic Waves (book), **L. A. Ware.** Pitman Publishing Company, New York, N. Y. Page 125.



R. D. TEASDALE (A '46)

(Electrical Engineering Department, Georgia Institute of Technology, Atlanta, Ga.)


## Electromagnetic Induction Intensifier

*To the Editor:*

Dr. Slepian in his electrical essay entitled "Electromagnetic Induction Intensifier" (*EE, Aug '49, pp 677–8*) comments on the two prevailing concepts for the generation of a voltage before describing his invention. Of these two concepts, change in flux linkage or change in the number of "lines of force" enclosed and cutting of "lines of force," it seems to me that the latter concept is the simplest and applicable in all instances. It alone explains the unipolar generator.

Dr. Slepian's objection to the cutting theory, namely, that we cannot tag or mark a particular "line of force" when it shrinks or expands, applies also to the linkage or change in number of lines theory. In fact, no one has ever seen a "line of force" or definitely proved that such a line exists. In this respect the theory of magnetism is in about the same state as it was when conceived by Faraday and subsequently amplified by Maxwell. Maxwell's concept of "molecular vortices" is still the best picture of the mechanism involved in the creation of an electromagnetic field.

Now, referring to Dr. Slepian's invention, in the illustration, he assumes that a current flowing in the conductor causes a "line of force" to start from a point and move around the conductor to form a closed loop, but before the loop is closed, the moving end is pushed forward by another "line of force" at right angles to it, thus causing a spiral to be formed.

If we follow Maxwell's conception of the generation of a "line of force," we have to start with a closed loop surrounding the conductor and in close contact therewith. When the current starts to flow, the "line of force" expands like an elastic band or garter—the amount of expansion being determined by the intensity or amperage of the current, but in all instances, maintaining its closed form. In other words, there is no open end to be pushed forward by another magnetic line at right angles to it, therefore no spiral can be formed. The expanding "line of force" may be bent,

inclined, or distorted, but it will be a closed loop—from the beginning to the end.

Dr. Slepian's invention is not valid, as he well knows.

A. B. REYNDERS (A '07)

(Retired Works Manager, Westinghouse Electric Corporation, Springfield, Mass.)

*To the Editor:*

Dr. Slepian's monthly satire on the stodgy thinking which the technical schools and colleges in the United States perpetuate is most enjoyable.

However, if he will bear with me he will see that he is guilty of doing a job only halfway when he wrote of his "Electromagnetic Induction Intensifier." Such sloppiness is most regrettable indeed.

In loose terms, the "pitch angle" of his spiralling intensified flux varies directly with the amount of direct current flowing in the intensifying element. Therefore, if he will put his flux into "low pitch" (high rpm to pilots) he will greatly increase the number of linkages, and by reducing his intensifying current to zero ("flat pitch") he will get infinite flux linkage.

I am not only greatly disappointed in the Doctor, I am shocked.

JOHN A. MOODY (A '48)

(Aeronautical Field Service Engineer, Sperry Gyroscope Company)

## Space Charge Theory Exploded

*To the Editor:*

In the electrical essay entitled "The Space Charge Theory Exploded" (*EE, Jan '49, p 29*), it was validly shown that the space charge action in a vacuum tube is not due to a repulsion of electrons back to the filament. This followed from the fact that for a cylindrically symmetrical charge distribution the electrostatic force on a charge due to all charges at larger radii is zero.

However, while the space charge does not repel the electrons back towards the filament, it does retard the current in a different way The essential point is that the amount of charge on the filament necessary to maintain it at some given negative potential with respect to the plate is not fixed, but depends upon the space charge surrounding it. Thus, while an electron that has left the filament is not repelled back by the space charge, this space charge causes the filament itself to produce a lesser force on the electron.

It is readily shown that the charge on the filament necessary to maintain a fixed voltage across the tube varies with the amount of space charge. Roughly speaking, this is so because the essentially constant voltage battery "finds it more difficult" to send electrons towards a region already enclosed by a cloud of negative charge (that is, toward the filament). More precisely, the explanation is as follows: By definition, the potential difference between plate and filament is the work done (or obtained) in moving a unit positive charge from one to the other. Now, let us imagine that such a unit positive charge could be released at the plate, so that it would be drawn toward the filament. Then the electrostatic force exerted upon it at any point of its path would be due to both the filament charge and all the space charge at smaller radii from the filament Therefore the voltage across the tube (that is, the work that would be done by the field in moving the unit positive charge from plate to filament) can only remain fixed if an increased negative space charge corresponded to a decreased number of electrons in the filament.

PAUL REICHEL

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## Static D-C Transformer

*To the Editor:*

George Keinath, in the September issue of *Electrical Engineering* (*EE, Sep '49, p 827*), suggests that the German, E. Besag, is the original inventor of the static d-c transformer.

I would like to draw attention to "The Transformer for Measuring Large Direct Currents" by Harris J. Ryan, in AIEE *Transactions* for April 1901, volume 18 pages 169–83.

C. F. ELWELL (M '13)

(Consulting Engineer, Palo Alto, Calif.)

## Industrial Exploration

*To the Editor:*

I would like to express my complete agreement with many of the points emphasized by Dean Smith of Iowa State College in his article on "Industrial Exploration and Development" (*EE, Sep '49, pp 777–81*). His remarks on general personnel relations are sound and to the point, and, it seems to me, are applicable to engineering departments in general, as well as to research departments. Where, if not in the field of engineering, should one deal with facts? And it is a fact that men will do better work when they know the general aim of their work, when they feel they are fairly compensated for their efforts (not necessarily financial compensation), and when they are not subjected to minor and avoidable irritations.

In regard to the tendency of the checking department to change designs developed by the research department, it should be recognized that such changes may sometimes be valuable. My own experience in installing various types of equipment and circuits and in laying out projects for others to install has shown me that the advice of practical, experienced "field" men is frequently useful and enlightening.

NORTON SAVAGE (A '41)

(Assistant Electrical Supervisor, United Engineers and Constructors, Sewaren, N. J.)

## Magnetic Speedometer

*To the Editor:*

I should like to point out what is, in my opinion, a fundamental error in Dr. Slepian's answer to his electrical essay on a magnetic speedometer for aircraft (*EE, May '49, pp 449–50*).

Dr. Slepian says that if a conducting metal rod is placed in a uniform electric field $E$, parallel to the "lines of force," an electromotive force of magnitude $El$ is set up in the rod.

This, I think, is not true.

The conducting rod distorts the otherwise uniform electric field, so as to remain an equipotential body; that is, lines of electric force enter one end of the rod, and leave the other end, thus inducing charges in the rod. No electromotive force is set up since all parts of the conducting rod are at the same potential.

When an observer (in an airplane) moves horizontally in the earth's magnetic field, he does not observe merely this magnetic field. He also "observes" (as Dr. Slepian showed) a horizontal electric field, perendicular to his direction of motion, due to his velocity relative to the earth's magnetic field.

The problem of a conducting rod in an airplane is therefore exactly the problem of a conducting rod in an electrostatic field. Charges are induced in the rod, but there is no question of an electromotive force being generated in the rod.

A method of measuring the velocity of the airplane would be to have a gold leaf at the end of the rod (which would measure the induced charge).

This would not, however, give valuable results for the reasons which Dr. Slepian gave concerning variations of the earth's electric field.

N. KERRUISH

(17, Bowen Road, Rugby, Warwickshire, England)

## Electromagnetic Induction

*To the Editor:*

I am grateful to Norton Savage for bringing up at this time the classical artifice used by the "flux linking school" to illustrate the applicability of $\epsilon=-\frac{d\phi}{dt}$ to the Faraday disk, Figure 1 (*EE, Jul '49, p 645*). In the article on electromagnetic induction (*EE, May '49, pp 441–7*) I demonstrated that the flux linking law when *correctly* applied does not give the correct result and hence the Faraday disk is an example where $\epsilon=-\frac{d\phi}{dt}$ is not applicable. I will now show that $\epsilon=-\frac{d\phi}{dt}$ as applied by Mr. Savage still does not give the correct result. Mr. Savage obtained the correct result for this special problem by using a method specifically designed to give the correct answer from the flux linking law when a constant uniform magnetic field is involved. In general once an answer to a "specific" problem is known it is a simple matter to develop an incantation, ritual, or technique which will give the known answer from any formula. Of course if the technique is correct in general or even for a very narrow range of phenomena it must also give the correct result for other specific problems. Hence as a simple test consider the Faraday disk in a uniform time varying magnetic field $B=B_0 \cos \omega' t$.

Now according to the technique used by Mr. Savage

$$\phi=BR^2\frac{\theta}{2}$$

$$\phi = \frac{B_0 R^2}{2} \theta \cos \omega' t$$

$$\frac{d\phi}{dt} = \frac{B_0 R^2}{2} \left[ \theta \frac{d \cos \omega' t}{dt} + \frac{d\theta}{dt} \cos \omega' t \right]$$

$$\theta = \omega t$$

$$\frac{d\theta}{dt} = \omega$$

$$\frac{d\phi}{dt} = \frac{B_0 R^2}{2} \left[ -\omega t \omega' \sin \omega' t + \omega \cos \omega' t \right]$$

hence

$$\epsilon = \frac{B_0 R^2}{2} \left[ \omega \omega' t \sin \omega' t - \omega \cos \omega' t \right]$$

This answer is obviously incorrect for $\epsilon \rightarrow \infty$ as $t \rightarrow \infty$. As may easily be verified by experiment the correct result is given by

$$\epsilon = \int_0^R V \times B \cdot dl$$

$$\epsilon = B_0 \cos \omega' t \int_0^R \omega r \, dr$$

$$\epsilon = \frac{B_0 R^2}{2} \omega \cos \omega' t$$

The sign of $\epsilon$ is with respect to the positive co-ordinate system direction which is opposite to the positive circuit direction therefore with respect to the latter

$$\epsilon = -\frac{B_0 R^2}{2} \omega \cos \omega' t.$$

GEORGE I. COHN (A '43)

(Assistant Professor of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill.)

# NEW BOOKS • • • • •

**The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.**

PRODUCTION CONTROL. By L. L. Bethel, W. L. Tann, F. S. Atwater, and E. E. Rung. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1948. 289 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. Originally developed for use by war production workers, this book has been rewritten in terms of current practice to meet the needs of a collegiate program in management engineering. The general method of presentation is: statement of the basic principles; illustration of the principles through applica-ion to specific industrial situations; and case problems to which the student applies the principles involved.

RADIO RECEIVER DESIGN, PART II. By K. R. Sturley. John Wiley and Sons, New York, N. Y., 1948, 480 pages, diagrams, charts, tables, 8¾ by 5½ inches cloth, $5.50. An American reprint of the original British edition. It contains a full discussion of the progressive stages involved in the design of radio receivers for frequency modulation and television reception. Starting with audio frequency amplifiers, it deals with the power output stage, power supplies, automatic gain control, and various types of frequency control.

RADIO RECEIVERS AND TRANSMITTERS. By S. W. Amos and F. W. Kellaway. Second revised edition. Chapman and Hall, Ltd., London, England, 1948, 356 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, 25s. Provides a bridge between pure science and applied radio. A knowledge is assumed of some elementary radio, electricity, and mathematics. With this as a basis, the various aspects of radio and radio equipment are considered. This second edition contains expanded material on negative feedback, on microphones, and on leaky grid detectors.

BIBLIOGRAPHIC SURVEY OF CORROSION, 1945, a Compilation of Corrosion Abstracts. By R. D. Misch, J. T. Waber, and H. J. McDonald. Corrosion Research Laboratory, Illinois Institute of Technology, Chicago, Ill. Published by National Association of Corrosion Engineers, 905 Southern Standard Building, Houston, Tex., 1948. 129 pages, 11¼ by 8¼ inches, cloth, $5. The abstracts included in this survey are divided into two main classes, general material and patents, each classified into nine main groups: types of attack; investigations in corrosion; effects of specific media; effects in specific equipment; resistance of materials; methods of prevention; coatings; removal of corrosion products; general and miscellaneous, including books. References included have been taken from the 1945 issues of the six principal indexing services covering the field. A detailed subject index and an author index are included.

CHAMBERS'S TECHNICAL DICTIONARY. Edited by C. F. Tweney and L. E. C. Hughes. Revised edition with supplement. Macmillan Company, New York, N. Y., 1948. 976 pages, diagrams, tables, 8¼ by 5½ inches, cloth, $6.50. Defines terms used in pure and applied science, in engineering and construction, in manufacturing and the skilled trades. Additions to this edition include such items as the atomic bomb, recently named elements, and newly coined technical words. For the more than 40,000 terms listed a careful identification is made of the field to which the definition applies.

CYBERNETICS, OR CONTROL AND COMMUNICATION IN THE ANIMAL AND THE MACHINE. By N. Wiener. John Wiley and Sons, New York, N. Y.; Hermann et Cie, Paris, France, 1948. 194 pages, diagrams, charts, 9¼ by 6 inches, cloth, $3. Describes the application of statistical mechanics methods to communications engineering. Its subject matter ranges from such control mechanisms as servomechanisms, mathematical calculators, and automatic pilots, to the nerves and brain of the human body. The discussion considers human control functions and mechanicoelectrical systems designed to replace them.

DESIGN OF INDUSTRIAL EXHAUST SYSTEMS. By J. L. Alden. Second edition. Industrial Press, New York, N. Y., 1948. 252 pages, diagrams, charts, tables, 9¾ by 5½ inches, cloth, $3.50. Describes how to design, build, or buy an exhaust system that will meet the requirements of law or of industrial hygiene. It includes exhaust ventilation, low-pressure pneumatic conveying, design of hoods and piping, and structural details, as well as the selection of dust separators, centrifugal and axial flow fans.

ELECTRIC RESISTANCE STRAIN GAUGES. By W. B. Dobie and P. C. G. Isaac. English Universities Press, Limited, London, England, 1948. 114 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, linen, 15s. This book is of value to the experimenter or development engineer who is required to evaluate strains in load bearing machines or structures. It deals with the various difficulties encountered in using electric resistance strain gauges and suggests methods for overcoming them. The basic mathematical and electronic theory needed in the use of this tool is included.

ELECTROLYTIC POLISHING AND BRIGHT PLATING OF METALS. By S. Wernick, foreword by U. R. Evans. Alvin Redman Limited, 4 Fitzroy Street, Fitzroy Square, London, W. 1, England, 1948. 243 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, 30s. Emphasizing basic principles, this book surveys new developments in this branch of industry from both the practical and chemical aspects. Working details of present processes for steel, nickel, aluminum, copper, and silver are given. An extensive bibliography and patent literature are included.

ELEKTRISCHE WELLEN. By W. O. Schumann, Carl Hanser Verlag, Munich, Germany, 1948. 340 pages, diagrams, tables, 9¾ by 6½ inches, cloth, 28.50 r.m. Intended for students and those who deal with electrical phenomena, this book is based on a series of lectures given at the Technical College of Munich. It summarizes basic principles, but assumes an elementary knowledge of electromagnetic fields and mathematics needed to compute their properties. The Maxwell equations, reflection of electromagnetic waves, and transverse and longitudinal waves are among the topics considered.

ENGINEERING WITH RUBBER. Edited by W. E. Burton. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1949. 486 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6.50. Based on information from technical catalogues and bulletins, this book gives a comprehensive picture of the engineering, design, and maintenance principles which must be considered in using rubber in industry. The physical and chemical properties of various rubber compounds and the typical dimensions and structural details of industrial rubber products are discussed in detail.

ENGINEER'S SKETCH-BOOK OF MECHANICAL MOVEMENTS, DEVICES, APPLIANCES, CONTRIVANCES, AND DETAILS. By T. W. Barber. Seventh edition. E. & F. N. Spon, Ltd., 57 Haymarket, London, S. W. 1, England, 1948. 355 pages, diagrams, tables, 8½ by 5¼ inches, cloth, 15s. Provides, side by side, brief descriptions and sketches of the various devices in use for accomplishing many specific mechanical movements or works. Such devices as accumulators, bearings, cams, doors, gears, handles, jets, levers, pivots, rotary engines, swivels and tappets are included.

FOUNDATIONS OF MODERN PHYSICS. By T. B. Brown. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1949. 391 pages, illustrations, diagrams, charts, tables, 9¼ by 5¾ inches, cloth, $5. Considering the descriptive, theoretical, experimental, and practical aspects, this book explains the experiments and discoveries by which the theories of modern physics have been established. Some of the recent developments in physical knowledge added to this new edition are in microwaves, radar, nuclear physics, cosmic rays, kinetic theory, and electronics. A background of elementary algebra and geometry is assumed, but the use of advanced mathematics is avoided.

(THE) FOURTEEN SYSTEMS OF UNITS. By W. R. Varner. O.S.C. Cooperative Association, Corvallis, Oreg., 1948. 217 pages, diagrams, tables, 9¼ by 6 inches, cloth, $3.75. Presents the basic physical quantities and equations used in the six systems of units in mechanics and the eight systems used in electricity. The problem of dimensions in the different systems of electric units is clarified by deriving all of the systems in use from a general basic system. Tables are included which permit translation from one system to any of the others.

ADVANCES IN ELECTRONICS, Volume I. Edited by L. Marton. Academic Press, New York, N. Y., 1948. 475 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $9. This first volume of a projected yearly publication contains critical and integrated reviews of specific topics in the field of physical electronics and in selected fields of engineering electronics. The ten articles in this book were written by specialists and deal with oxide-coated cathodes, secondary electron emission, television pickup tubes deflection of beams of charged particles, mass spec-

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troscopy, particle accelerators, ionospheric research, cosmic radio noise, the frequency-modulation broadcast band, and electronic aids to navigation.

APPLIED MATHEMATICS FOR ENGINEERS AND SCIENTISTS. By S. A. Schelkunoff. D. Van Nostrand Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 472 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $6.50. This book is devoted to those branches of mathematics which are needed in mathematical physics and engineering. It is divided into two parts, one considering general mathematical methods, and the other, special transcendental functions. Such topics are included as power series, vector analysis, differential equations linear analysis, Bessel functions, and Legendre function.

FREQUENCY MODULATION, FUNDAMENTALS, APPARATUS SERVICING. By N. Marchand, Murray Hill Books, New York, N. Y., and Toronto, Ontario, Canada, 1948. 409 pages, illustrations. diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5. Written with a minimum of mathematics, this practical book covers the field of frequency modulation. It includes basic theory, transmitters, receivers, mobile equipment, installation, and servicing.

HANDBOOK OF INDUSTRIAL ELECTRONIC CIRCUITS. By J. Markus and V. Zeluff. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 272 pages, diagrams, tables, $11^1/_4$ by $8^1/_4$ inches, cloth, $6.50. More than 400 industrial electronic circuits are included in this manual. It gives for each circuit a clearly drawn diagram along with a condensed discussion of how it works, performance characteristics, and applications. The values of all the important components are given to facilitate conversion of the theoretical circuit to actual practice.

HANDBOOK OF REFRIGERATING ENGINEERING. By W. R. Woolrich and L. H. Bartlett. Third edition. D. Van Nostrand Company, New York, N. Y., London, England, Toronto, Ontario, Canada, 1948. 730 pages, diagrams, charts, tables, $7^1/_2$ by 5 inches, cloth, $8.50. Beginning with fundamental units, primary refrigerants, and charts and tables of thermodynamic characteristics, this handbook continues with detailed descriptions of refrigerating equipment and processes. Special adaptations to ice making, quick freezing, freezer storage, air cooling, and marine refrigeration are dealt with separately. Lubrication, instruments and controls, piping details, and safety measures also are discussed.

MICROWAVE ANTENNA THEORY AND DESIGN (Massachusetts Institute of Technology, Radiation Laboratory Series 12). Edited by S. Silver. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1949. 623 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $8. Provides a comprehensive survey of theory and design techniques for microwave antennas and a full discussion of antenna measurement methods. Following a survey of pertinent electromagnetic and optical theory, various types of antenna feeds and the complete antenna systems used for producing all principal types of microwave beams are discussed. The aberrations and special features of microwave optical systems are considered in relation to rapid scan antennas.

ADVANCED DYNAMICS. By S. Timoshenko and D. H. Young. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 400 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5.50. The general principles of dynamics together with their applications in various engineering fields. Five self-contained chapters deal with the dynamics of a particle, of a system of particles, and of systems with constraints, as well as with the theory of small vibrations, and the rotation of a rigid body about a fixed point.

FOUNDATIONS OF NUCLEAR PHYSICS, WITH BIBLIOGRAPHY. Compiled by R. T. Beyer. Dover Publications, New York, N. Y., 1949. 272 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, cloth, $2.95. Contains facsimiles of 13 previously published fundamental studies as originally reported by the investigators. It also provides a comprehensive but unannotated bibliography of over 5,000 references to articles, classified under broad subject headings. Only last names of authors are given and only the first page of each article.

PHOTOELECTRICITY AND ITS APPLICATION. By V. K. Zworykin and E. G. Ramberg. John Wiley and Sons, New York, N. Y., Chapman and Hall, London, England, 1949. 494 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $7.50. Replacing the second edition of "Photocells and Their Application," this book presents up-to-date data on the properties, preparation, and applications of photoelectric devices. The emphasis is on the practical aspects of the subject. Following a historical introduction, the principles and preparation of photoelectric devices are discussed. The remaining chapters provide detailed consideration of a variety of applications. The last chapter discusses the range available for future developments.

RADIOACTIVE MEASUREMENTS WITH NUCLEAR EMULSIONS. By H. Yagoda. John Wiley and Sons, New York, N. Y., Chapman and Hall, Ltd., London, England, 1949. 356 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $5. This co-ordinated study on the use of photographic emulsions in measuring radioactivity explains the principles underlying the chemical and photographic operations involved, and describes working methods in the fields of biology, radiochemistry, metallurgy, mineralogy, and nuclear physics. The bibliography includes 700 items dealing with the use of photographic emulsions in radioactive measurements.

TABEL TIL BRUG VED ADDITION AF KOMPLEKSE TAL (TABLE FOR USE IN THE ADDITION OF COMPLEX NUMBERS). By J. Rybner and K. S. Sørensen. Jul. Gjellerups Forlag, Copenhagen, Denmark, 1948. 95 pages, charts, tables, $12^1/_2$ by $9^1/_4$ inches, paper, 20 Danish Kroner. The object of this table is to facilitate calculations with complex numbers by making possible the addition or subtraction of such numbers in polar form. The numerical value $R$ and the phase angle $\alpha$ of the sum are given as functions of the variables $\tau$ from 0 to 1 at intervals of 0.01 and $\varphi$ from 0 to 180 degrees at intervals of 1 degree. The explanatory text is printed in parallel columns of Danish and English.

ULTRASONICS. By B. Carlin. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 270 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5. Deals with the many engineering aspects of the ultrasonic field, including the vital theory as well as a great deal of practical information. Electronic considerations and outlines of circuits are specifically reviewed, and mechanical and electrical design of ultrasonic systems are discussed. Particular features are the information on testing materials, agitation, ultrasonic transducers, and ultrasonic systems. The interesting work being done in biological, physical, and chemical fields is presented.

NUMERICAL METHODS OF ANALYSIS IN ENGINEERING (SUCCESSIVE CORRECTIONS). By H. Cross and others. A Symposium at Illinois Institute of Technology, Chicago, Ill., arranged and edited by L. E. Grinter. The Macmillan Company, New York, N. Y., 1949. 207 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, cloth, $5.80. Contains papers on methods and techniques of numerical analysis which are applicable in many fields of engineering and science. Divided into four sections, the first three discuss numerical methods based upon physical concepts, numerical solutions of equations for state of stress, and applications of numerical methods to heat transfer. Surveys and bibliographies of numerical methods make up the final section.

AIRCRAFT ELECTRICAL SYSTEMS, HYDRAULIC SYSTEMS, AND INSTRUMENTS. By R. H. Drake. The Macmillan Company, New York, N. Y., 1949. 393 pages, illustrations, diagrams, $9^1/_2$ by 6 inches, cloth, $5.60. Written in nontechnical language, this book is intended for use as a classroom text, reference, or guide for self-instruction. It is divided into three sections: The fundamentals of electricity and aircraft electric systems; the fundamentals of hydraulics and aircraft hydraulic systems; and the principles underlying the construction and operation of aircraft and engine instruments.

ELECTRONIC TIME MEASUREMENTS. (Radiation Laboratory Series, volume 20). Edited by B. Chance, R. I. Hulsizer, E. F. MacNichol, Jr., and F. C. Williams, 1949. 538 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $7. Presents the method of approach to the problems of time and distance measurement by manual and automatic means, and the practical circuits employed for these purposes. The important techniques of pulse data transmission and pulse-amplitude cancellation methods are included. A survey is made of techniques for radio distance and speed measurement. The use of new techniques for precision data transmission and for the relaying of the radar PPI to remote points is presented, and the use of supersonic delay devices for the cancellation of recurrent wave forms is discussed.

# PAMPHLETS • • • • •

**The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.**

**Isotopes and Their Application in the Field of Industrial Materials.** This 1948 ASTM Edgar Marburg Lecture discusses research, atomic power, and the applications of radioactive and stable isotopes. 28 pages. Available for $1 from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

**Program for Professional Engineering Education in Plastics.** Recommends undergraduate and graduate curricula for adoption by schools interested in establishing engineering courses in plastics. Copies of the brochure may be obtained from The Society of Plastics Engineers, Inc., Athens, Ohio.

**Engineering College Research Council Proceedings.** Contains 13 papers presented at the 1948 annual meeting of the council. Some of the topics dealt with are cancer research, high-temperature metallurgy, the petroleum industry, and sponsored research. Priced at $1. Available from the Engineering College Research Council of the American Society of Engineering Education, The State University of Iowa, Iowa City, Iowa.

**Three NBS Physics Publications.** In "Transmittance of Near Infrared Energy by Binary Glasses," RP1945, transmittance values are given for lithia-silica, alkali-silica, and lead-silicate glasses. "Absorption of Radio Waves Reflected at Vertical Incidence, a Function of the Sun's Zenith Angle," RP1939, is a study based on the diurnal variation of ionospheric absorption. "Destruction of Superconductivity by Current," RP1940, covers the reappearance of resistance in superconducting wires when the current is increased up to and beyond the critical value. Each is available at ten cents per copy from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C.

**Movies About Oil.** A catalogue of motion pictures about the oil industry, listing movies available from oil companies, trade and educational associations, and government, and telling how they may be obtained. Obtainable from the Oil Industry Information Committee, 670 Fifth Avenue, New York 19, N. Y.

**ASTM Panel Discussion on Influence of Nonferrous Metals and Their Compounds on Corrosion of Pressure Vessels.** Considers the deposition of nonferrous metals and their compounds, either as sludges or as metals, in pressure vessels. 45 pages. Available at $1 from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.